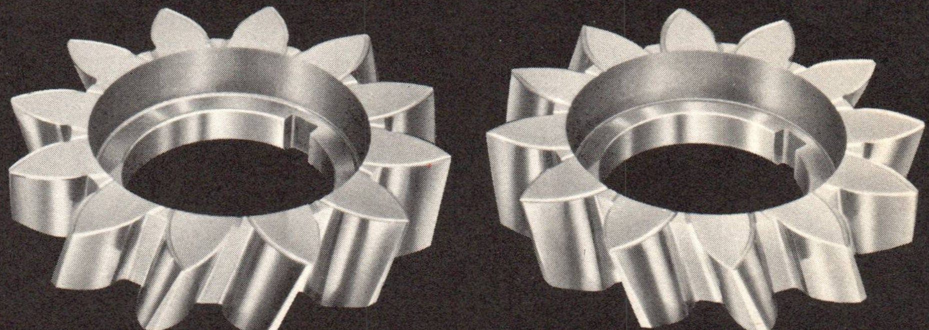
Know your Shaper Cutters

INVOLUTE FORM
GEAR SHAPER CUTTERS
FOR SPUR
AND HELICAL GEARS,
INVOLUTE SPLINES
AND HERRINGBONE GEARS



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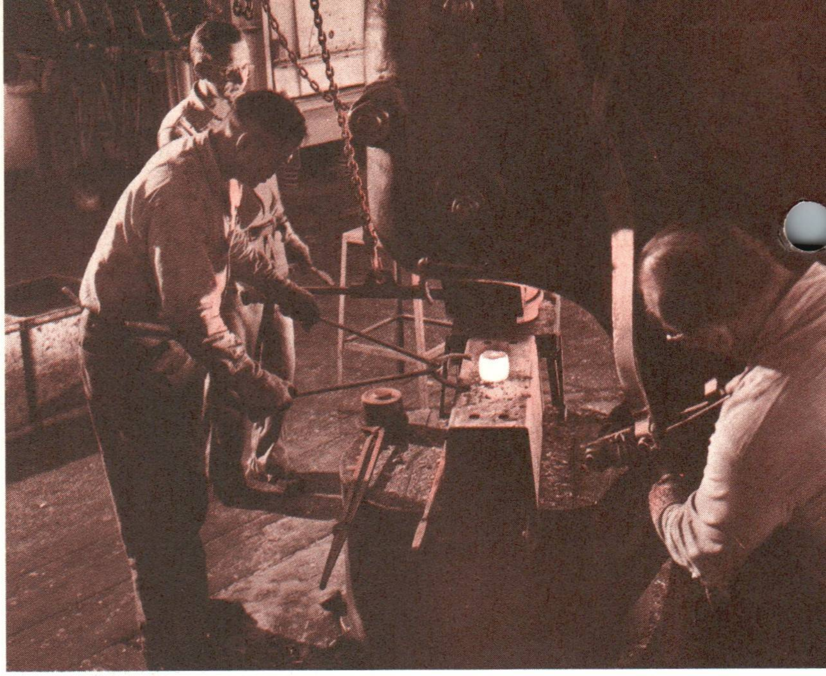

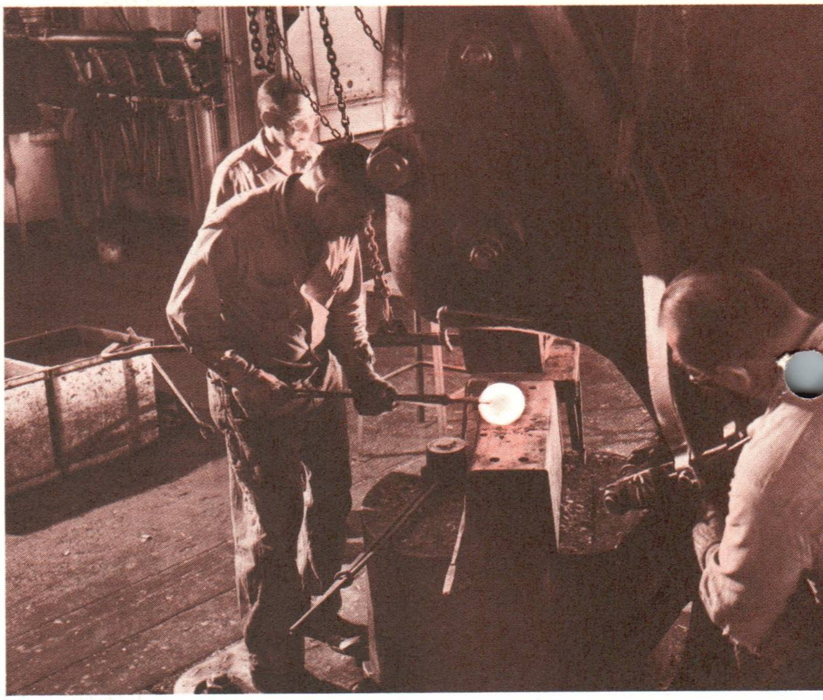

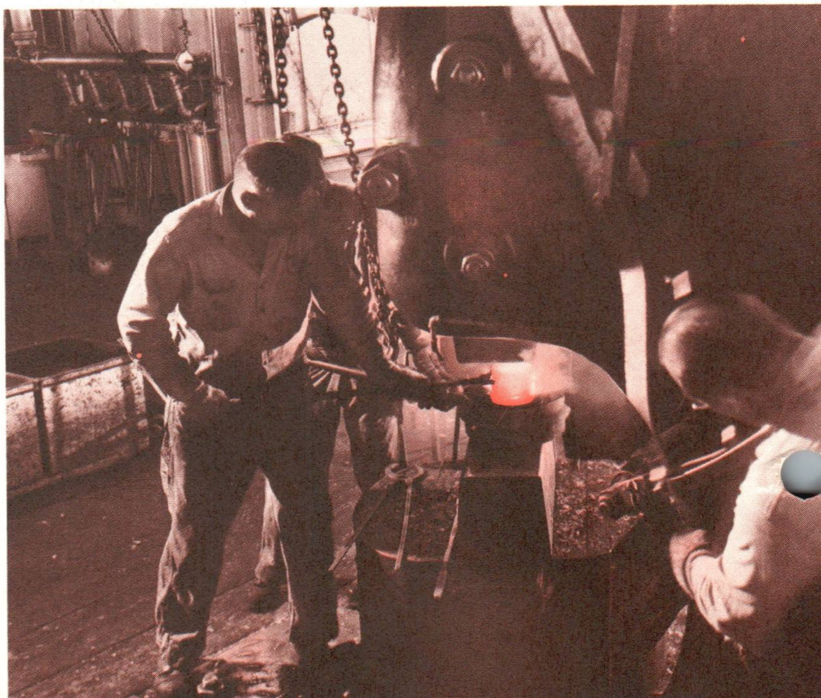

Three steps at Illinois Tool Works in forging a high speed steel blank for a gear Shaper Cutter. Note die ready at hand for forging the counterbore when shaping the body.

For detailed discussion of ITW metallurgical control, send for: "Metallurgy in Tool Design & Production"

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Grinding the "Involute" on a special Illinois Tool Works generating grinder.

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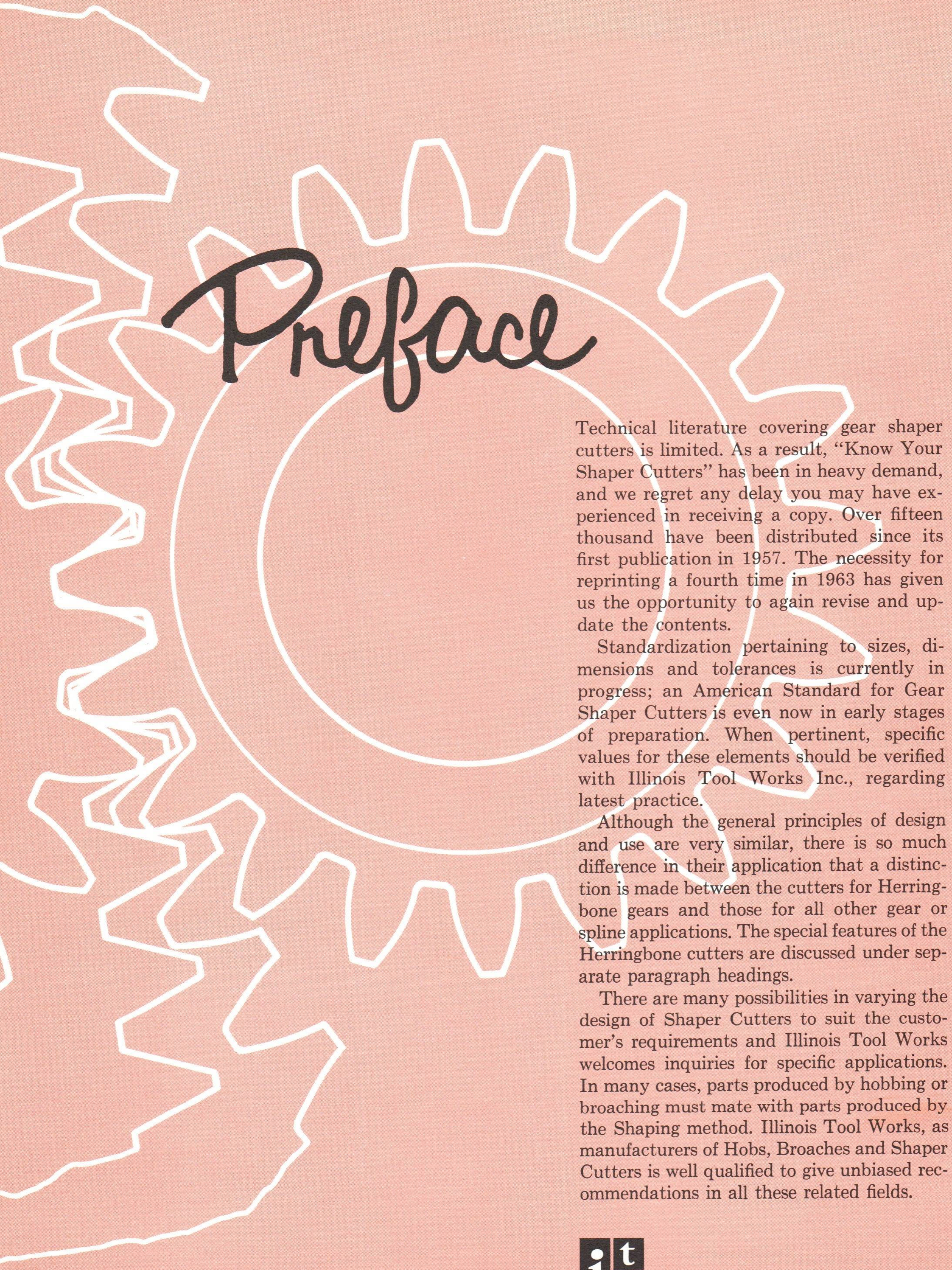

Preface

Technical literature covering gear shaper cutters is limited. As a result, "Know Your Shaper Cutters" has been in heavy demand, and we regret any delay you may have experienced in receiving a copy. Over fifteen thousand have been distributed since its first publication in 1957. The necessity for reprinting a fourth time in 1963 has given us the opportunity to again revise and update the contents.

Standardization pertaining to sizes, dimensions and tolerances is currently in progress; an American Standard for Gear Shaper Cutters is even now in early stages of preparation. When pertinent, specific values for these elements should be verified with Illinois Tool Works Inc., regarding latest practice.

Although the general principles of design and use are very similar, there is so much difference in their application that a distinction is made between the cutters for Herringbone gears and those for all other gear or spline applications. The special features of the Herringbone cutters are discussed under separate paragraph headings.

There are many possibilities in varying the design of Shaper Cutters to suit the customer's requirements and Illinois Tool Works welcomes inquiries for specific applications. In many cases, parts produced by hobbing or broaching must mate with parts produced by the Shaping method. Illinois Tool Works, as manufacturers of Hobs, Broaches and Shaper Cutters is well qualified to give unbiased recommendations in all these related fields.

Ordering information

In general, the proper Shaper Cutter for a given job can be supplied if the customer supplies only the following:

1—Shaping machine to be used and hole size for the cutter.
2—Blueprint for the gear to be cut.
3—Blueprint for the mating gear.

Unless otherwise stated cutters will be supplied without the features shown under 8 and 9 below.

While it is desirable in all cases to supply part prints of the gear to be cut **and the mating gear,** it is necessary to have such prints or equivalent specifications when special form features are specified.

If the customer wishes to establish the cutter specifications the following is required:

1—Diametral Pitch
2—Pressure Angle
    If cutters are for Helical gears state whether DP and PA are in Normal or Transverse plane.
3—Nominal Pitch Diameter of Cutter
4—Hand of Cutter and Helix Angle, if for Helical Gears—**RH Cutters are used for LH external gears and vice versa. For internal gears the cutter is the same hand as the gear.**
    (Is there an existing Lead Guide to be used?)
5—Hole Diameter
6—Disk, Deep Counterbore, Hub or Shank Type Special blank details such as Keyway, etc.
7—Shank Size and Type
8—Special Features
    a—Indicating Band
    b—Precision Tolerance (includes Indicating Band)
    c—Gap Type
    d—Combination Roughing and Finishing
9—Special Form Features (Give details)
    a—Topping
    b—Semi-topping (Chamfering)
    c—Protuberance
    d—Tangent flank
    e—Constant Approach flank
    f—Roughing, semi-finishing (pregrind or preshave)
    g—Full Radius Tip

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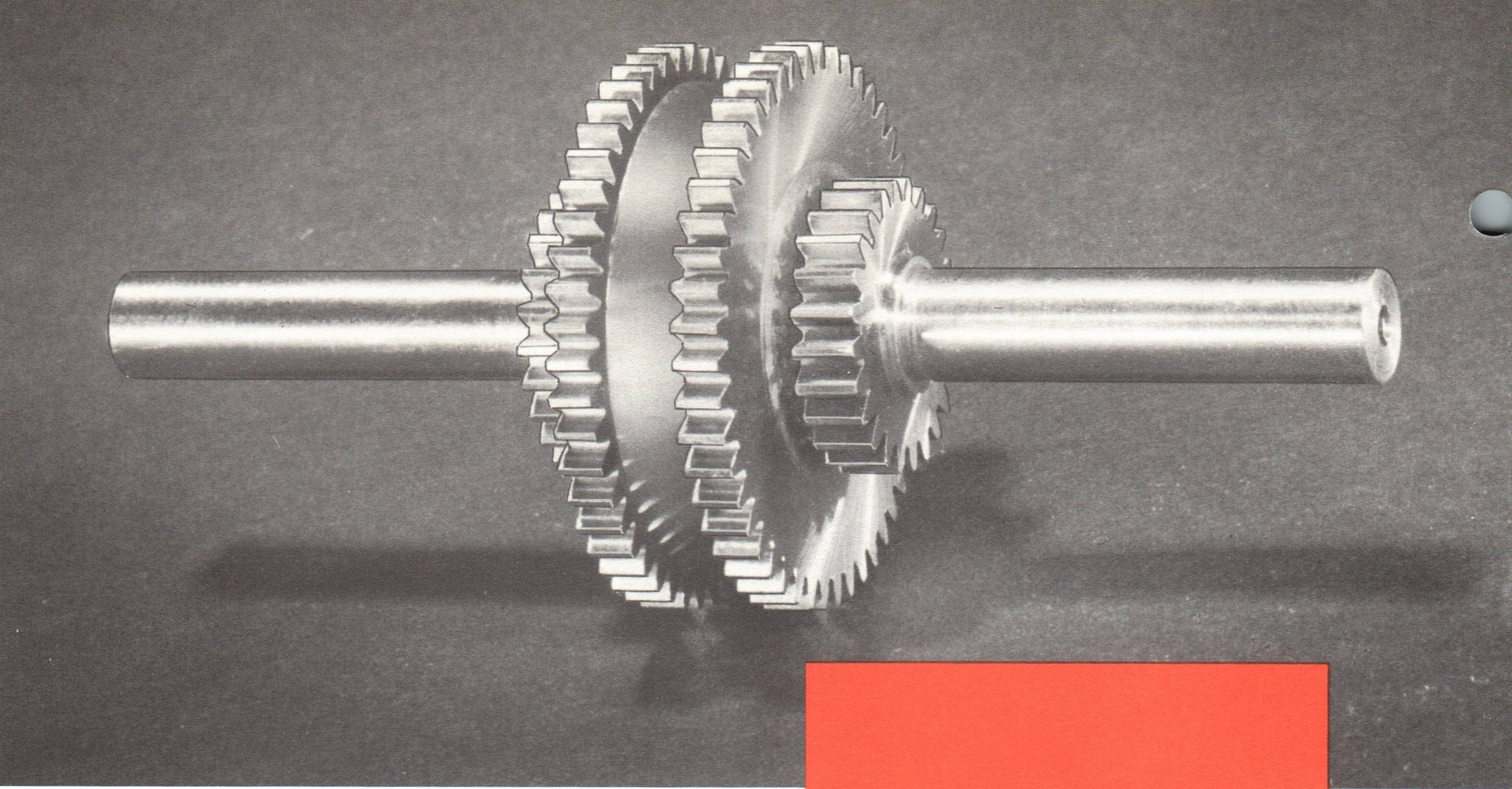


Figure 1—Cluster gear. The two outside members can only be cut by the Shaping method. Actually, the entire unit is cut with an involute Spur Gear Shaper Cutter.

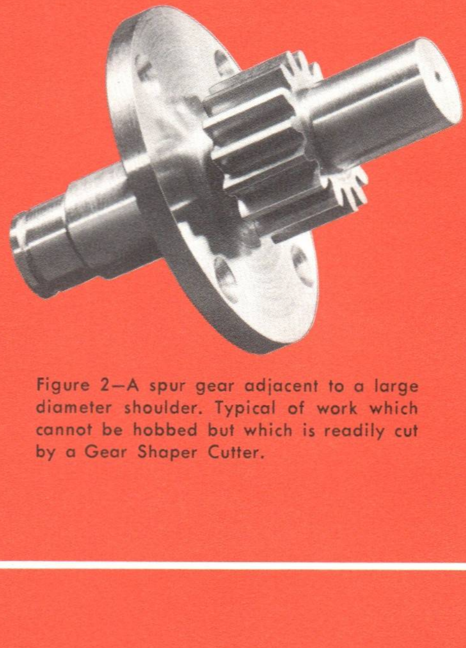


Figure 2—A spur gear adjacent to a large diameter shoulder. Typical of work which cannot be hobbed but which is readily cut by a Gear Shaper Cutter.

Field of Application

Certain types of gears can only be cut by Shaper Cutters or Herringbone Cutters. These are: cluster gears with close spacing (figure 1), gears near a large shoulder (figure 2), solid Herringbone gears (figure 3), or double helical gears with a narrow central clearance groove, and such items as gears with a tooth removed or a tooth space not cut. In addition, while high production open internal gears are frequently broached, most applications use Shaper Cutters.

The application of Shaper Cutters is by no means limited to the above special cases since they are more versatile than hobs and are also widely used for cutting all manner of standard external gears and pinions with excellent tooth finish and a high order of accuracy.

Since the increment of circumferential feed per stroke can be varied, and made as small as desired, the generating flats can be reduced in prominence as compared to the normal pattern produced in hobbing.

(The foregoing applies with equal force to involute splines and other similar involute applications.)

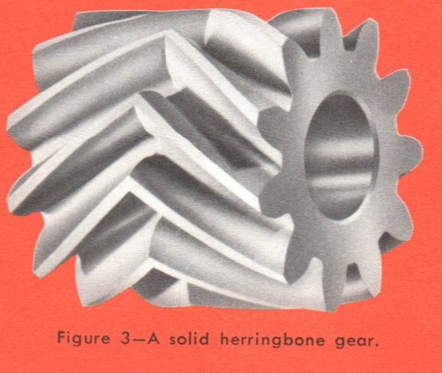


Figure 3—A solid herringbone gear.

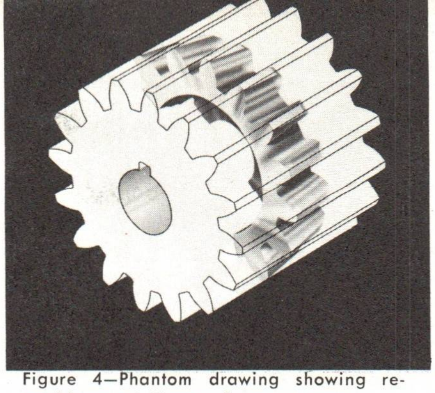


Figure 4—Phantom drawing showing resemblance of Shaper Cutter to gear.

The Shaping method

In order to use Shaper Cutters to best advantage, certain basic facts about the equipment and method must be understood. Some of the limitations given are imposed, not only by the method, but by the shape and dimensions of the part and the gear tooth geometry.

Cutting gears with Shaper Cutters is a true planing or shaping process involving a reciprocating motion of the tool with chips removed only on one direction of the stroke. On the return stroke no metal is cut and the cutter and work must be separated so that the cutting edges are not damaged by dragging them backwards through the cut. This relieving action is comparable to "Clapper Box" action on a planer. In some gear shaper machines the work table moves away from the cutter on each return stroke and on other types of machines the relieving mechanism is built into the cutter head. The direction and extent of this relieving motion is sometimes critical and must occasionally be varied to suit the particular type and size of cutter and gear.

In a gear shaper the cutting action extends across the entire face of the gear. Since the cutting action starts at one definite point on the gear periphery and continues around to the starting point *with a slight overlap*, there is the possibility that one tooth at this point of overlapping action will become slightly thinner than the other teeth.

In a gear shaper the radial runout of the cutter is reproduced directly upon the gear in a pattern determined by the ratio of diameters. If, for example, the shaper cutter is twice the diameter of the gear being cut the total runout of the shaper cutter will appear as a slight change in diameter at one point on the gear.

Shaper cutters are mounted on the overhanging end of a spindle* with no outboard support to reduce deflection of the spindle as the cutter passes by the gear. In addition, the work piece itself is usually mounted without an outboard support. As a result the deflection may become excessive with dull cutters operating on tough materials.

Where the ratio of workpiece length to diameter is large on internal gears or splines, the shank type shaper cutters required are slender and likely to bend in the cut.

The side relief angle on the teeth of shaper cutters is held to a minimum (range 1° 45′ – 3° 30′) to secure maximum usable life from the cutter. This amount of relief is low as compared to many other types of cutting tools and for some applications must be increased from the usual amount of approximately 2° to the maximum value shown. In the case of helical cutters, the side relief angle is sometimes made greater on one side of the tooth than on the other.

Shaper Cutters are more versatile than hobs in the range and variety of applications, but they are somewhat more limited in one respect. While hobs generate small fillets in external gears these fillets will not interfere with a mating external gear of any size or interfere with a rack. Shaper Cutters, however, will produce larger fillets than will a hob and these larger fillets may interfere with a mating gear of larger diameter than was considered in the Shaper Cutter design. A Shaper Cutter will not cut the same tooth depth on work gears with different numbers of teeth. Also, Shaper Cutters will trim the tips of gear teeth under some circumstances while hobs never will unless specifically designed to do so.

**Except for machines used in cutting Herringbone gears.*

Typical shaping applications and vario gear shaper cutters used.

Shaper Cutters and Herringbone Cutters generate involute form gear teeth on a gear blank by a planing action while the cutter and gear blank rotate in timed relation. Typical processes used are illustrated in Figures 9 through 12. Various types of Shaper Cutters are shown in figures 13 thru 23.

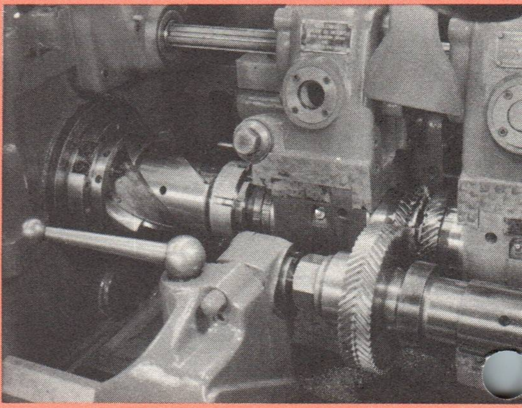


Figure 9—Cutting staggered tooth double helical gea with 2 Herringbone cutters.

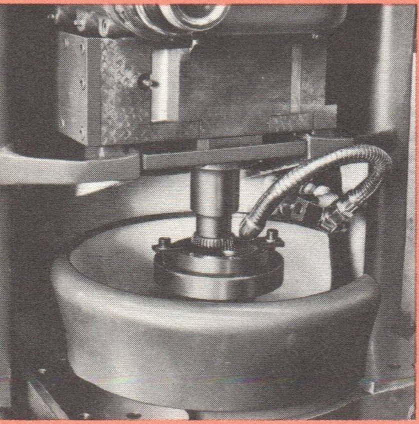


Figure 10—Cutting internal gear.

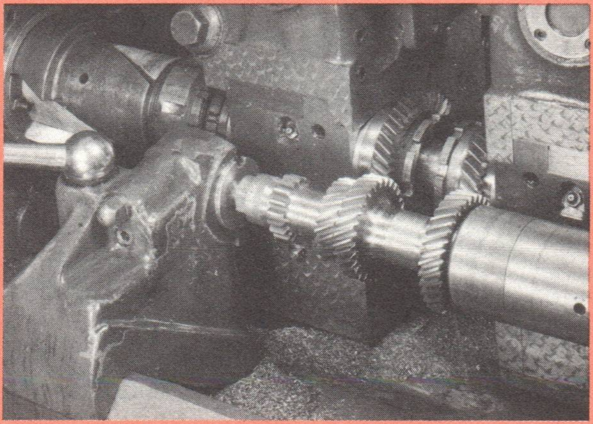


Figure 11—Generating two different diameters simultaneously.

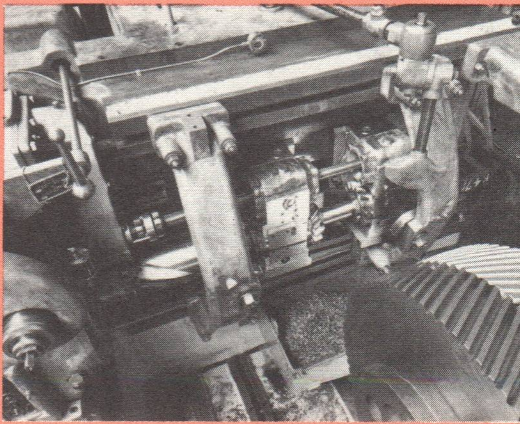
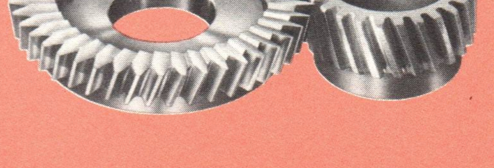


Figure 12—Shaping a Herringbone Gear.



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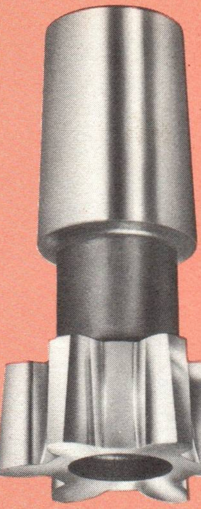


Figure 17—6-tooth 5DP Shank Type Spur Gear Shaper Cutter 14½° PA. Note junction of involute and Radial Flank.

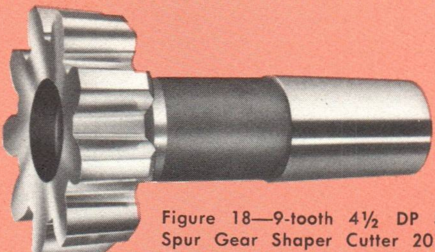


Figure 18—9-tooth 4½ DP Shank Type Spur Gear Shaper Cutter 20° PA. Note junction of involute and Radial Flank. Compare with Figure 17 and notice difference in Outside Angle.

Figure 13—Disk type Spur Gear Shaper Cutter.

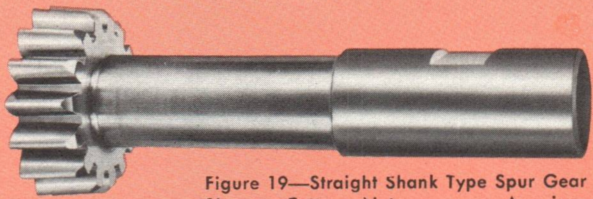


Figure 19—Straight Shank Type Spur Gear Shaper Cutter. Not common American practice.

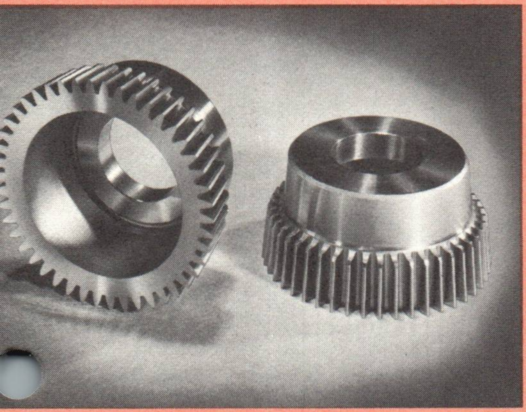


Figure 14—Deep Counterbore Spur Gear Shaper Cutter.

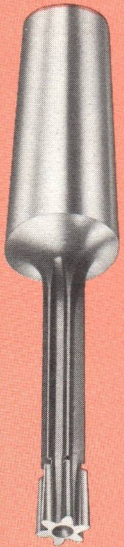


Figure 20—Taper Shank Spur Gear Shaper Cutter with ribbed shank.

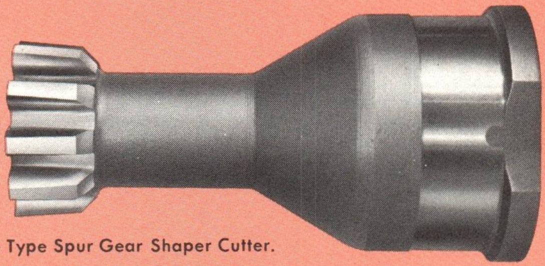


Figure 21—Hub Type Spur Gear Shaper Cutter.

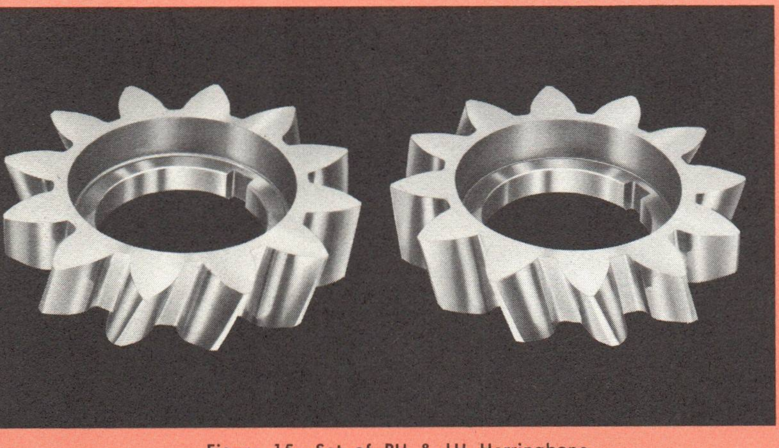


Figure 15—Set of RH & LH Herringbone Cutters shown before Lip Sharpening.

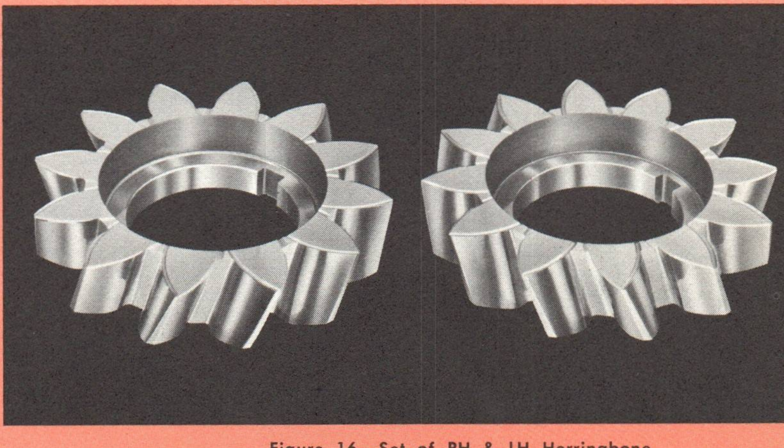


Figure 16—Set of RH & LH Herringbone Cutters shown after Lip Sharpening.

Figure 22—Left Hand Helical Pinion and the Right Hand Helical Gear Shaper Cutter used to cut it.

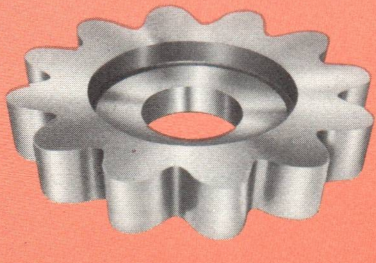
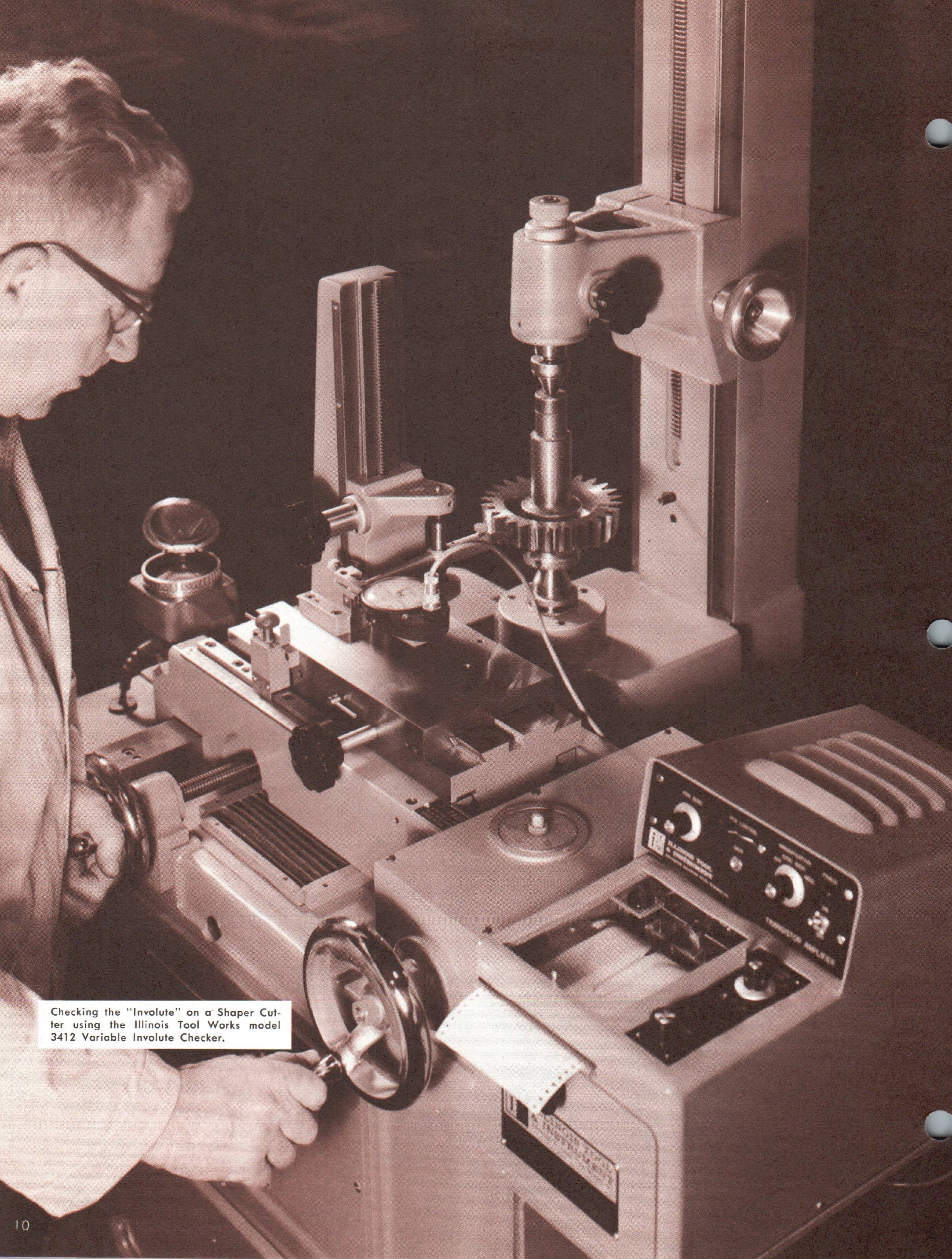


Figure 23—Disk Type Shaper Cutter (unground form) for American Standard Roller Chain Sprocket.



Checking the "Involute" on a Shaper Cutter using the Illinois Tool Works model 3412 Variable Involute Checker.

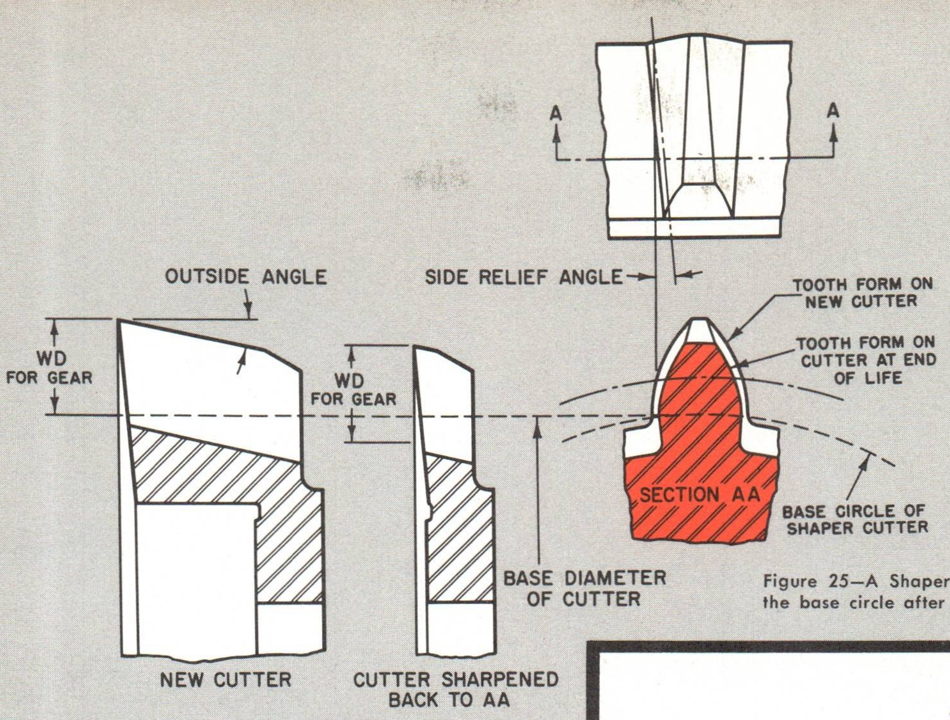


Figure 25—A Shaper Cutter which cuts below the base circle after it is sharpened back.

THE BASIC GEAR SHAPING PROCESS — Just as a hob may be idealized and compared to a rack, so may the Shaper Cutter be compared to a gear having the same number of teeth. Disregarding the face sharpening angle and the side relief angles, the cutting edges of a Shaper Cutter at any stage of its life are best pictured as part of a phantom gear of the particular size. The analogy is illustrated by figure 4*, page 7.

The Shaper Cutter is a full generating tool just as much as a hob, but it has an involute of *finite* base circle radius whereas a hob (rack tooth) has an involute of nearly *infinite* base circle radius. The line drawing figure 24 shows how one Shaper Cutter can generate a rack, an internal gear or an external gear to convey some idea of the universality of the Shaper Cutter. The number of teeth can be varied (within limits) on the gears being cut provided that the pitch, helix angle, and pressure angles are the same.

THE BASE CIRCLE — In spite of the variation in dimensions and appearance of a shaper cutter tooth as the cutter is sharpened back, it is important to remember that the base circle is constant throughout the life of the cutter. Since the base circle is constant throughout the cutter life, the base pitch also remains constant. See figure 25 for cutter view (new and at the end of its life) with the base circle shown.

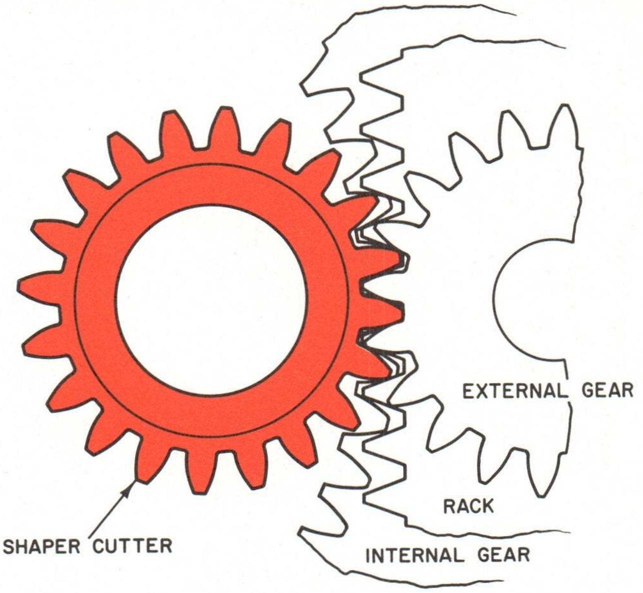


Figure 24—Illustration shows a single Shaper Cutter is capable of cutting various gear types.

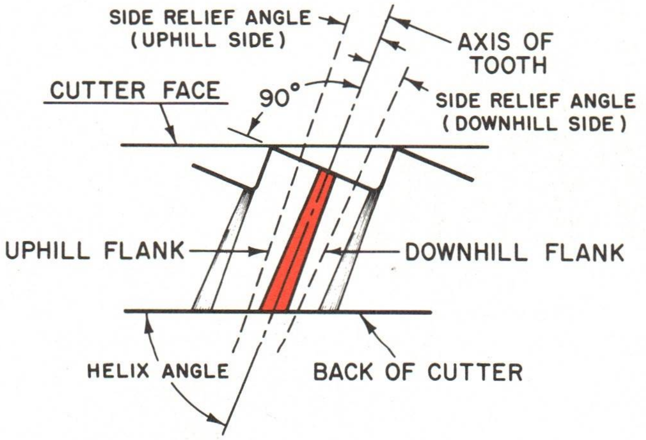


Figure 26—Tooth on a right hand helical gear Shaper Cutter showing side relief angles and normal sharpening.

**Because of this superficial resemblance to a gear, shaper cutters are called Pinion type cutters by the British. See British Standard Specification—Pinion Type Cutters for Spur Gears—B.S. 2887-1957.*

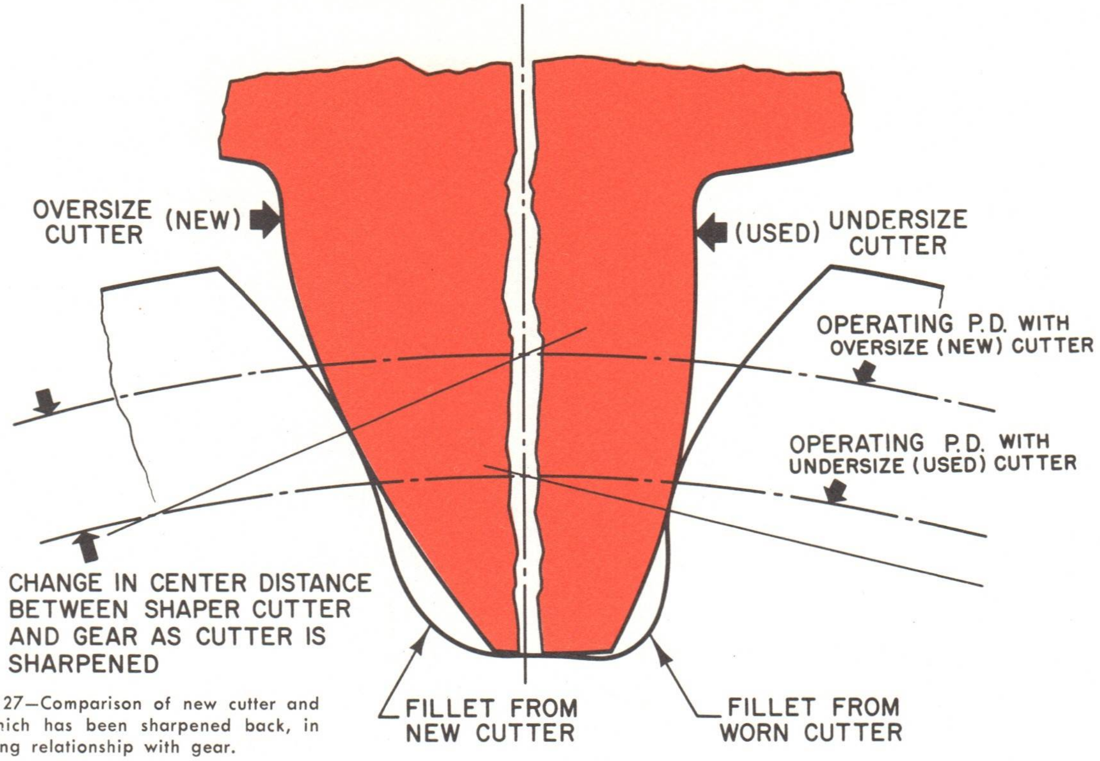

OVERSIZE CUTTER (NEW)
(USED) UNDERSIZE CUTTER
OPERATING P.D. WITH OVERSIZE (NEW) CUTTER
OPERATING P.D. WITH UNDERSIZE (USED) CUTTER
CHANGE IN CENTER DISTANCE BETWEEN SHAPER CUTTER AND GEAR AS CUTTER IS SHARPENED
FILLET FROM NEW CUTTER
FILLET FROM WORN CUTTER

Figure 27—Comparison of new cutter and one which has been sharpened back, in operating relationship with gear.

On spur gear Shaper Cutters the same diameter of base circle is used to generate both sides of the cutter tooth and the same is true with Herringbone cutters. However, the actual size of the base circle for the cutter is not the same as the base circle of a gear of equivalent size. There must be an adjustment in base circle diameter for the cutter to correct for face sharpening angle and side relief angles.

On helical gear shaper cutters with "normal" sharpening (or some lesser or greater angle than "normal", see figure 26) different base circle diameters are used to generate the involutes on the two sides of the cutter tooth. They also are adjusted for diameter because of the compound angle on the tooth face, and the side relief angles.

CUTTER PITCH DIAMETER – When a Pitch Diameter is given for a Shaper Cutter, it is a *Nominal* Pitch Diameter given for identification and to establish the basic size. When new, the shaper cutter usually is made with an oversize operating diameter; when sharpened back, the operating diameter gradually becomes basic, then undersize in regards to the nominal value. The limitation imposed by this action is one element in determining the usable length of tooth and is a design consideration which is the responsibility of the cutter manufacturer. See figure 27.

GEAR FILLETS – The further the operating (rolling) diameter is away from the root diameter of the gear being cut, the greater the fillet at the root of the gear. Then, as the shaper cutter is sharpened back, it will produce smaller and smaller fillets in the gear. See figure 27. Occasionally, at the end of the usable life of the shaper cutter, this action may result in undercutting of the gear tooth profile near the root on external gears.

The size of the permissible fillet must be evaluated in reference to the mating gear and not the gear being cut. The larger the mating gear the greater the danger of interference*. Therefore, the maximum amount of oversize for a new Shaper Cutter is determined by the relationship between the number of teeth in the cutter and number of teeth in the mating gear. Standard Shaper Cutters are made with an optimum amount of oversize for average conditions.

CUTTER OVERSIZE – In order to build as much usable life as possible into each Shaper Cutter for external gears, they are usually made oversize with respect to the nominal pitch diameter when new. In addition to the limitations on the amount of oversize based on the maximum permissible gear fillet there is a strength limitation – as the amount of

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**This is one reason why data on the mating part is desirable and frequently necessary to design the best Shaper Cutter for a given gear.*

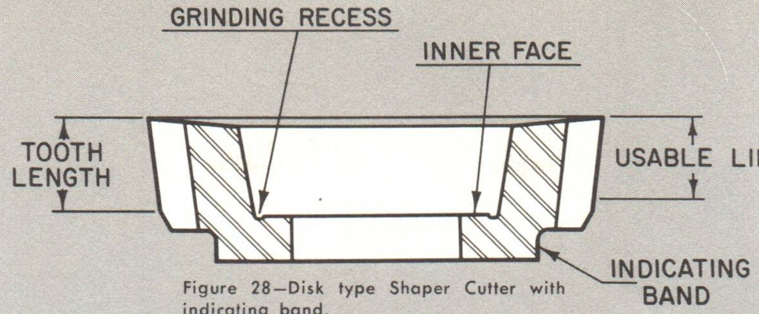


Figure 28—Disk type Shaper Cutter with indicating band.

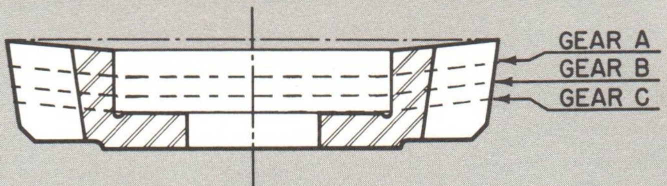


Figure 29—Three stages in life of a disk type gear Shaper Cutter.

oversize is increased, the width of flat at the outside diameter is decreased. The amount of oversize must not be so great as to result in a weak tooth tip on the Shaper Cutter. In some cases, particularly for internal gears, no cutter oversize is permissible, and for some applications Shaper Cutters must be undersize when new.

CUTTER UNDERSIZE – The amount undersize on diameter permitted for a given cutter at the end of its sharpening life is determined by the allowable trimming of the involute at tips of the gear teeth being cut if cutting occurs below the base circle of the cutter.

USABLE LIFE OF A CUTTER – The usable life of a cutter is determined by the maximum permissible amount of oversize, by the maximum permissible amount of undersize and by the side relief angles on the cutter teeth. In the case of cutters designed to produce modifications in the gear tooth profile or designed to produce such features as chamfers on the gear teeth, further limitations on the amount of usable life in any one cutter may be imposed.

Since the effect of oversize and undersize is relative to the size of both the shaped gear and the mating gear and is complicated by the size of the Shaper Cutter, the pitch, the pressure angle and tooth modifications, Shaper Cutters are best tailored for a specific job to secure maximum product quality and maximum life.

However, standard constructions and thicknesses have been determined for those cutters which are to do a variety of work*.

When new, these cutters generate fillets which permit operation with mating gears which have up to 75% more teeth than the cutter. After sharpening back they may produce some tip modification (trimming), but to the end of their usable life the tip modification will not be so excessive as to impair the normal functioning of the gears. Since cutters with small numbers of teeth, particularly with 14½° Pressure Angle, are the most likely to cause trouble in this respect, the user is advised to consult Illinois Tool Works if product quality requirements are severe and the smaller 14½° Pressure Angle cutters are to be used.

MEASURE OF USEFUL LIFE – The chamfer on a Shaper Cutter is a guide to usable life, see figure 28. Sharpening, however, is usually not continued fully to the chamfer because sufficient metal in relation to tooth strength and the load imposed by the cutting operation must be left to avoid tooth breakage. In addition, it is good practice to check the gear quality as the end of usable life approaches to make sure that excessive trimming of the gear tooth tips is not taking place. Generally, life is also indicated by the approach of the 5° sharpening angle to the inner face of the cutter on the disk type.

General purpose Shaper Cutters may reach the end of their usable life on a specific gear as at A in figure 29, and yet have additional life available to B in figure 29, for example to cut a different size gear to the same quality and design specifications. Similarly, the same Shaper Cutter might be used to point C for different gear design and quality specifications.

**See Illinois Tool Works price catalog for standard stock Shaper Cutters.*

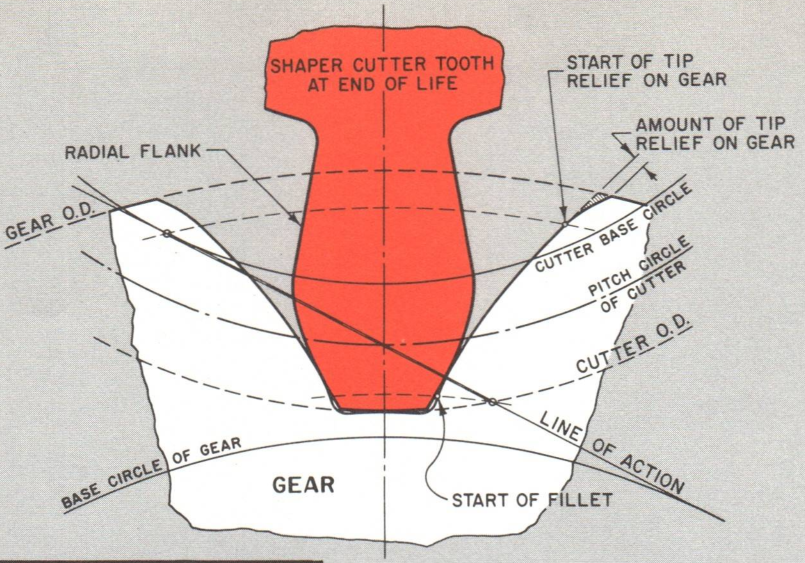


Figure 32—Excessive trimming of tip of gear tooth by flank of gear Shaper Cutter tooth.

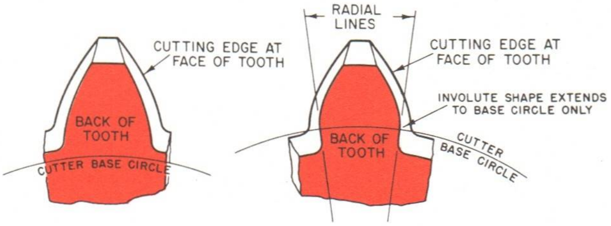

CUTTING EDGE AT FACE OF TOOTH
BACK OF TOOTH
CUTTER BASE CIRCLE
RADIAL LINES
CUTTING EDGE AT FACE OF TOOTH
INVOLUTE SHAPE EXTENDS TO BASE CIRCLE ONLY
BACK OF TOOTH
CUTTER BASE CIRCLE

Figure 30—Contrast between back and front on two gear Shaper Cutters having different design specifications.

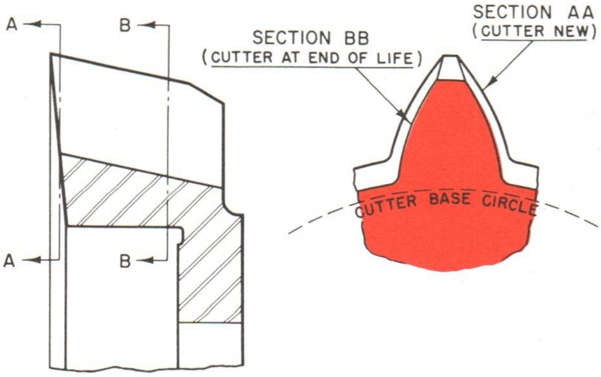


Figure 31—Gear Shaper Cutter with base circle below form at all points in life.

TOOTH SHAPE — FRONT AND BACK — Figure 30 shows the radical change in tooth appearance often encountered in viewing some Shaper Cutters from the back. This difference between cutters is due to the difference in diameter of the Shaper Cutters relative to their respective Base Circles. In the case of the right-hand view in figure 30, the straight flanks below the Base Circle will come into action as the cutter is sharpened back and trim the gear teeth at the tip. Which shape is obtained on a given cutter depends on many variables and the specific job requirements.

THE OUTSIDE ANGLE — The angle on the outside diameter of a shaper cutter depends upon the pressure angle and the side relief angles. It will normaly be in the range of 3½° to 8°, but in special cases may be as low as 2° or as high as 16°. The higher the pressure angle on the cutter the lower will be the outside angle. Higher values of side relief result in greater outside angles. Theoretically, the outside angle should be a convex curve on cutters for external gears and a concave curve on cutters for internal gears to preserve exact depth relationships, but a straight line is an entirely satisfactory, practical design and is universally used and accepted.

THE FACE SHARPENING ANGLE — Most gear shaper cutters are designed and manufactured with a 5° (positive) face sharpening angle. In some cases as little as 0° is used and in some cases as much as 10° is specified. Whatever the angle used for design it must be maintained in sharpening the cutter or else the form produced by the cutter will be altered.

SHAPER CUTTER TOOTH MODIFICATIONS — Since the tooth form on a Shaper Cutter is produced by a generating action, any changes in the profile to produce undercut for shaving or grinding, tip relief on the gear tooth, chamfering, topping or compensation for heat treat distortion of gears requires special operations in manufacture. The following modifications are frequently required for specific applications and they must be tailored to the specific job.

APPROACH – On some Shaper Cutters the design is such that the base circle is below the cutting zone throughout the life of the cutter, see figure 31, and a full involute is produced up to the outside diameter of the gear being cut at all stages of the cutter life. However, on many Shaper Cutters some cutting action below the base circle on the cutter occurs as the cutter is sharpened back. See figure 32. Standard practice in making such cutters is to stop the involute generating action at such a point as to create Radial Flanks on the Shaper Cutter tooth below the cutter base circle. Since the junction of the involute form and the radial flank approximates a straight line lying in a plane parallel to the cutter axis instead of being parallel to the cutter outside diameter, the amount of tip relief produced on the gear constantly increases as the cutter is sharpened back. See figure 33.

The *INTENTIONAL* provision of this feature – so that tip relief on the gear will be produced at all stages of the cutter life – is called adding an "Approach." See figure 34.

Two types of "Approach" are used. The first type called "Tangent Approach," is created by stopping the rolling action in grinding the involute to produce a straight flank on the gear shaper tooth tangent to the involute profile at the desired depth. The junction of the involute and the tangent flank, as in the case of a Radial flank, approximates a straight line lying in a plane parallel to the cutter axis. Therefore, the tip relief produced on the gear varies during the life of the cutter. See fig. 35

The second type, called "Constant Approach," is produced by dressing a slight angle on the generating grinding wheel. In order to properly illustrate this type it is necessary to depart from the simplified drawings showing a straight root line parallel to the outside diameter of the cutter and actually show the curvature produced by the grinding wheel. See figure 36. The junction line on the cutter tooth flank between involute and approach surfaces is now a curve and closely approximates the taper on the outside diameter of the cutter. The tip relief produced on the gear

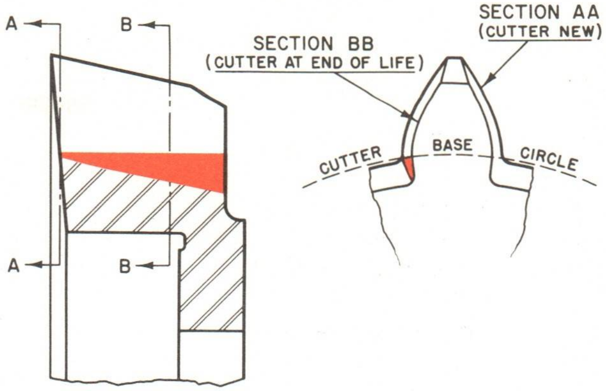


Figure 33—Gear Shaper Cutter with radial flanks which come into action as the cutter is sharpened back.

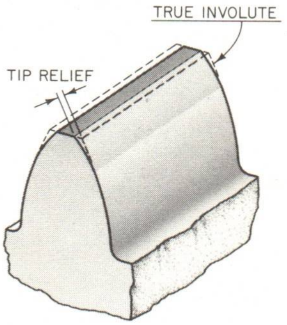


Figure 34—Tip relief on gear tooth.

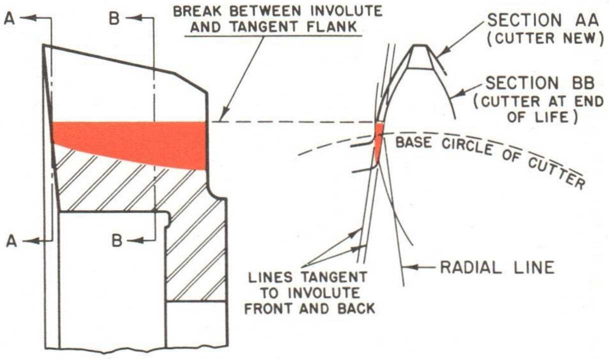


Figure 35—Gear Shaper Cutter with "Tangent Approach".

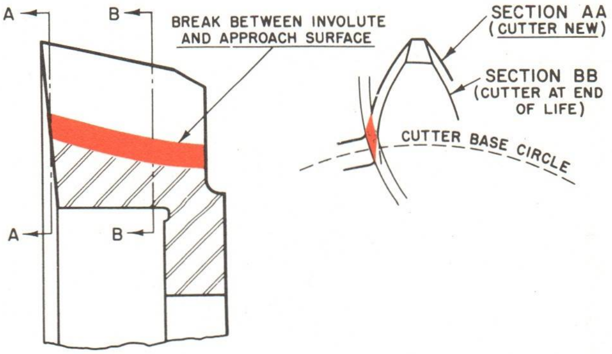


Figure 36—Gear Shaper Cutter with "Constant Approach".

is, therefore, nearly constant throughout the cutter life. To secure this "Constant Approach," the start of the modification must be above the base circle of the cutter.

In all cases where a Radial Flank, a Tangent Flank, or a Constant Approach Flank comes into action, the amount of tip relief produced varies with the number of teeth in the gear being cut.

RAMP – Where a Shaper Cutter is to be semi-topping – that is, to cut a chamfer on the tips of gear teeth, see figures 37 and 38 – a surface diverging outwardly from the involute is formed at the base of the shaper cutter tooth. See figure 39. The form of this surface is the same, and it is produced in the same manner as the "Constant Approach" shown in figure 36. Whereas the "Constant Approach" is at a very slight angle to the involute and removes at the most, only a few thousandths from the involute at the tip of the gear tooth, a Ramp is at a relatively large angle to the involute to produce the usual gear tooth chamfer. The Ramp produces a nearly constant chamfer although some variation is obtained during the cutter life due to the curvature from the grinding wheel diameter. In general, a semi-topping (chamfering) Shaper Cutter is suitable only for one specific gear design. If used for a gear with a different number of teeth, the chamfer produced will not be the same.

As a general rule, we do not recommend Constant Approach or Semi-topping Shaper Cutters of less than 12 teeth on 30° PA, 16 teeth on 20° PA or 30 teeth on 14½° PA.

DISTINCTION BETWEEN TIP RELIEF AND CHAMFER – Because a chamfer on the tip of a gear tooth is the same type of modification of the gear tooth profile as Tip Relief, differing only in degree, the Illinois Tool Works distinguishes between them by the following rule. See figures 40 and 41. Using the gear design specifications, if

$$\frac{\text{the min. specified radial distance B}}{\text{the max. specified circumferential distance A}} \text{ is less than 10,}$$

the gear tooth modification is a chamfer. If this value is greater than 10 the gear tooth modification is Tip Relief.

TOPPING CUTTERS – While Gear Shaper Cutters can be made to top the teeth on a gear, this feature is seldom specified for cutters partly because most gear shaping applications do not require it, and partly because it is generally held that the additional cutting load may decrease the overall accuracy. With

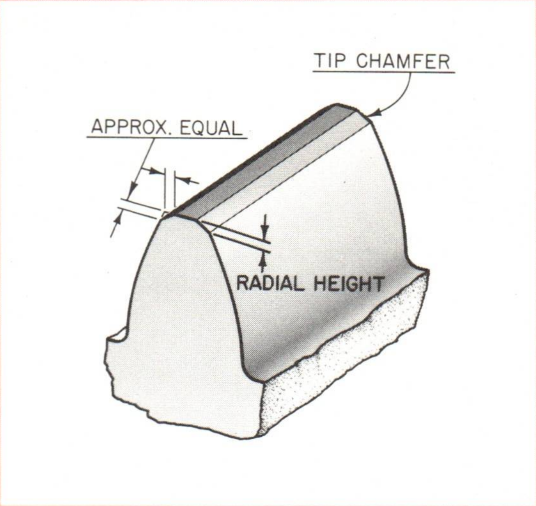


Figure 37—Chamfer on gear tooth.

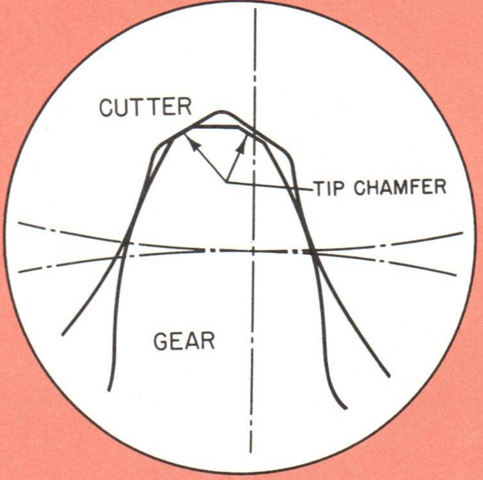


Figure 38—Gear Shaper Cutter with semi-topping feature at base of teeth.

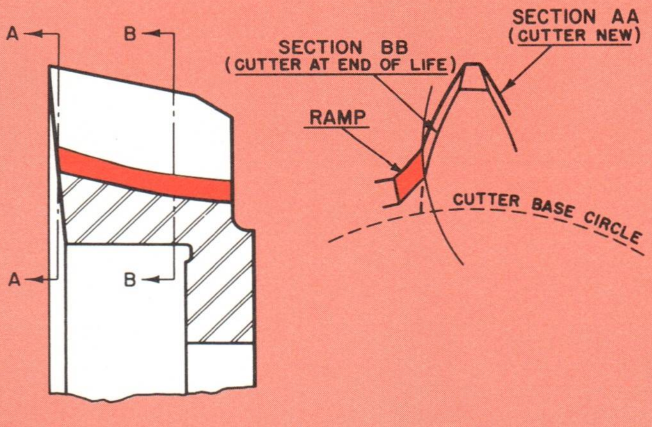


Figure 39—Gear Shaper Cutter with "Ramp" which chamfers the gear tooth.

"continuous chip" work materials, an additional difficulty is the chip crowding and poor chip flow with full topping action.

PROTUBERANCE – To provide an undercut at the base of the gear tooth where a gear is to be finished by shaving or grinding, an enlarged tip, called a "Protuberance," is provided adjacent to the outside diameter on each side of the Shaper Cutter tooth. See figure 42. As a general rule gear Shaper Cutters, finer than 16 DP, are not made with Protuberance.

FULL RADIUS TIP – A full radius on the top of the gear Shaper Cutter tooth produces a round root or fillet root on gears. See Fig.43.

HELICAL SHAPER CUTTERS – All the general principles discussed in connection with Spur Shaper Cutters, and all the general remarks in regard to the shaping method and applications apply with equal force to Helical Shaper Cutters. See figure 44. However, the following seven points are important to consider in Helical Shaper Cutter applications:

1—RH Helical Shaper Cutters are used to cut LH External gears and RH Internal gears.

2—LH Helical Shaper Cutters are used to cut RH External gears and LH Internal gears.

3—A Helical Shaper Cutter and its guide must have a definite mathematical relation to each other for cutting a specified helical gear. See page 21.

4—Two Helical Shaper Cutters and two guides are necessary to cut a pair (set) of helical gears.

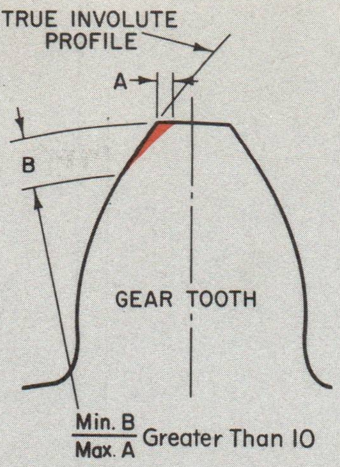


Figure 40—Tip Relief on gear tooth.

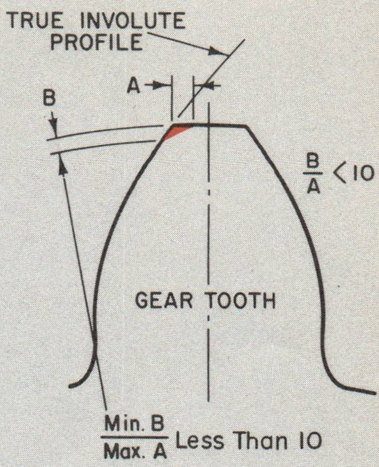


Figure 41—Chamfer on gear tooth.

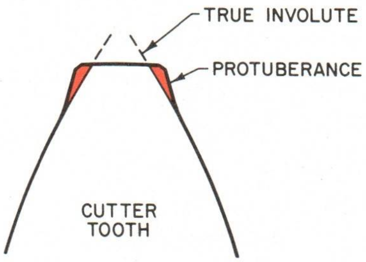


Figure 42—Gear Shaper Cutter tooth with protuberance.

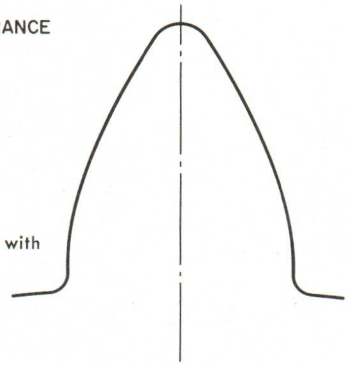


Figure 43—Gear Shaper Cutter tooth with full radius tip.

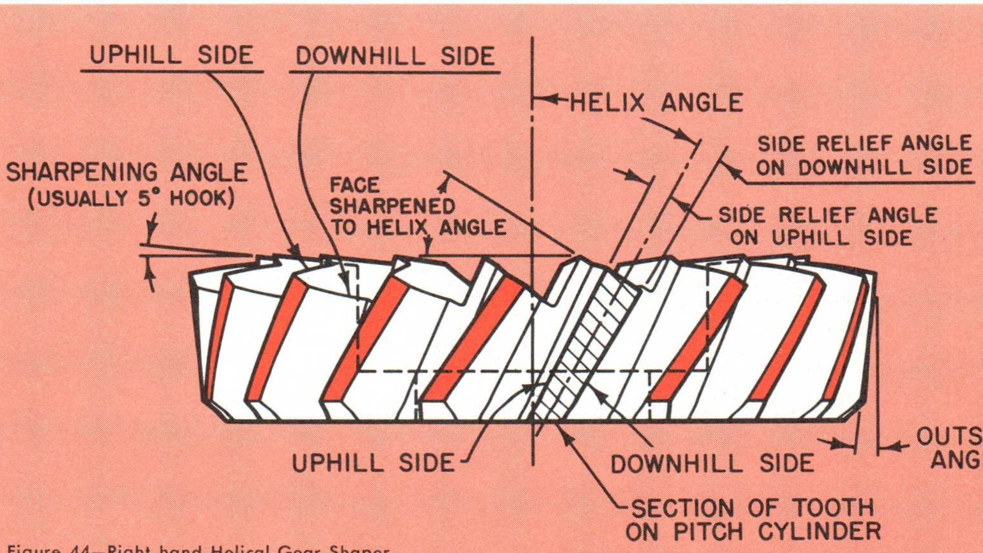

UPHILL SIDE
DOWNHILL SIDE
HELIX ANGLE
SIDE RELIEF ANGLE ON DOWNHILL SIDE
SHARPENING ANGLE (USUALLY 5° HOOK)
FACE SHARPENED TO HELIX ANGLE
SIDE RELIEF ANGLE ON UPHILL SIDE
UPHILL SIDE
DOWNHILL SIDE
OUTSIDE ANGLE
SECTION OF TOOTH ON PITCH CYLINDER

Figure 44—Right hand Helical Gear Shaper Cutter showing various elements.

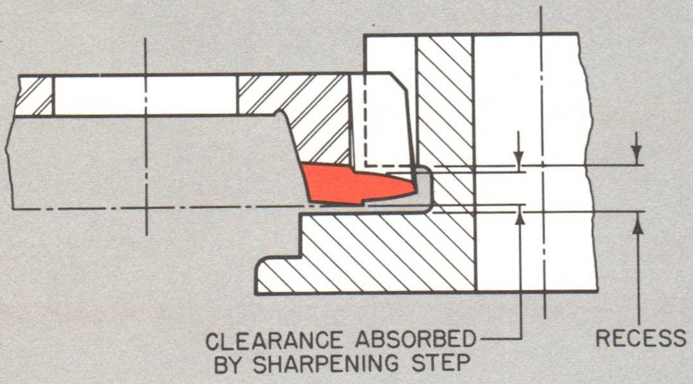


Figure 45—Helical gear Shaper Cutter in relation to clearance groove in part.

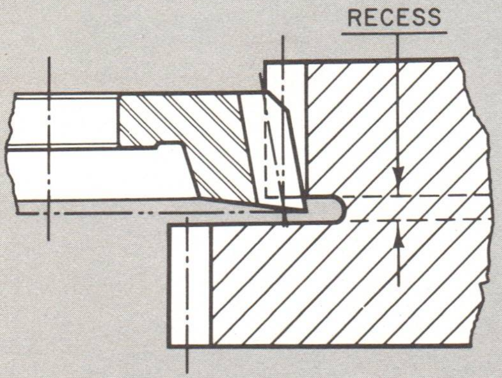


Figure 46—Spur gear Shaper Cutter in relation to clearance groove in part.

5—In general a wider recess for clearance at the end of the stroke is required for Helical Shaper Cutters. See figures 45 and 46.

6—While Helical Shaper Cutters may be sharpened by toolroom methods, production usage requires a special sharpening fixture. See figure 57, page 28.

7—A Helical Shaper Cutter designed for one specific gear cannot be used on some other gear unless the Helix Angle of the second gear is substantially the same as the gear for which the cutter was designed.

HERRINGBONE CUTTERS – These cutters are Helical Shaper Cutters distinguished by a special lip sharpening to make them suitable for cutting to the center of the face on a Herringbone gear. In this application there is no recess (or clearance groove) and the right and left-hand cutters, working alternately, cut toward the center of the gear face width and stop in the cut to make a solid continuous Herringbone tooth, see figure 3, page 6.

Herringbone Cutters, since they are used in pairs on the same spindle, must be manufactured as matched sets of one RH and one LH, in order to make both halves of the Herringbone gear alike. Also, care must be taken in sharpening these cutters to maintain matched cutters alike on diameter. As a convenience to the customer, the keyways are held in relation on a pair.

In general, Herringbone cutters are of coarser pitch than the average for Helical Shaper Cutters and are distinguished in appearance by the Lip Sharpening. This Lip Sharpening, which permits their use without a clearance groove in the gear, creates rake on both the cutting edges comparable to that secured by a Normal Grind on a Helical Shaper Cutter but leaves the cutting edges in the plane of the cutter face. Since the Lip Sharpening on both cutting edges follows the involute in the plane of the face, the cutter base circle calculations involve only the side relief angles.

The Lip Sharpening on the Downhill side of the tooth is a "dubbing" to reduce the rake around the involute. On the Uphill side of the tooth a groove is ground in the face, following the involute, to increase the rake. See Cutter B, page 22. This groove may take various forms and individual preferences exist as to the shape of the groove. The Illinois Tool Works supplies Herringbone cutters either without Lip Sharpening (plain flat face) to customers who wish to perform this operation themselves – see figure 15, page 9 – or finished with the Lip Sharpening, see figure 16, page 9.

CLEARANCE AT END OF STROKE – In designing spur gears to be cut by shaping, the recess must be sufficient to allow overtravel and reversal of the shaper spindle plus room for chips below the cutter face. See figure 46. In designing helical gears additional width of recess must be provided so that the Downhill cutting edge will clear the lower face of the gear while sufficient clearance exists for overtravel and chip room below the Uphill cutting edge. See figure 45. The axial distance between Uphill and Downhill edges at the base of the cutter tooth is frequently referred to as the sharpening step.

Where an adequate recess width is not obtainable for a helical shaper cutter an "off-normal" sharpening may be employed. See figure 47. By using a lesser angle than the cutter helix angle the sharpening step will be decreased. Such an off-normal sharpening may also in some cases improve the cutting action. It is also possible in case of necessity to use the flat face lip sharpening shown under the heading of Herringbone Cutters.

Modifying the type of grind on the face of a Shaper Cutter will change the profile produced on the gear tooth. Therefore, such modifications on an existing shaper cutter must be made with caution, and preferably designed into the cutter when manufactured.

While deliberate modifications can be made in the gear tooth form produced by a gear Shaper Cutter through special face grinds, such as radii or angles, alone or in combination, the practical difficulty involved in resharpening prevents the application of this principle.

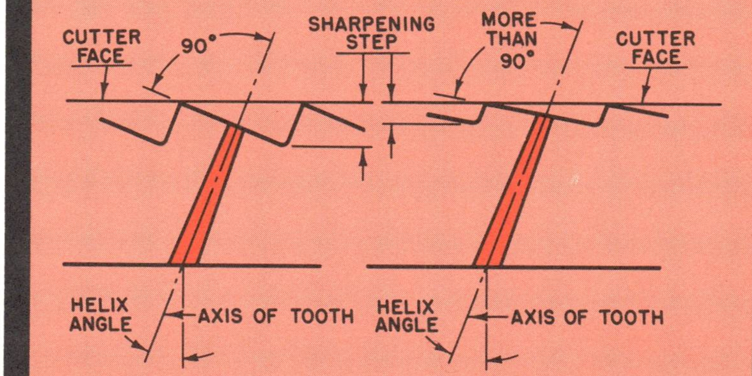


Figure 47

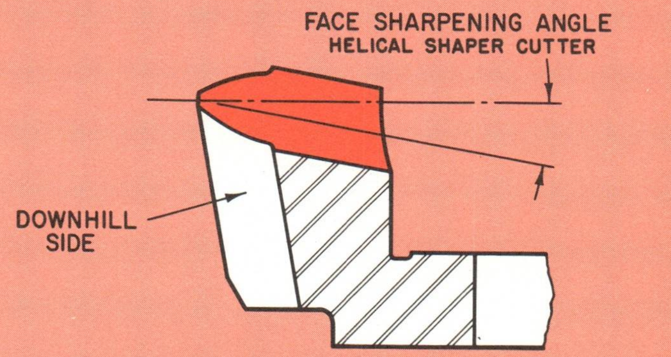


Figure 48—Sharpening details—helical gear Shaper Cutter.

RELATION OF NORMAL AND TRANSVERSE SPECIFICATIONS FOR HELICAL CUTTERS

DP = Diametral Pitch
NDP = Normal Diametral Pitch
TDP = Transverse Diametral Pitch
PA = Pressure Angle
NPA = Normal Pressure Angle
TPA = Transverse Pressure Angle
PD = Pitch Diameter

1—TDP = NDP × Cosine of cutter helix angle.

2—NDP = TDP × Secant of cutter helix angle.

3—Tangent of TPA =
Tangent of NPA × Secant of cutter helix angle.

4—Tangent of NPA =
Tangent of TPA × Cosine of cutter helix angle.

5—Number of Teeth in Cutter = PD × TDP.

CALCULATION OF BASE CIRCLE DIAMETER FOR SPUR SHAPER CUTTERS

Formulas:

1—Tangent of Corrected PA = Tangent of Nominal PA + (Tangent of Side Relief Angle × Tangent of Face Sharpening Angle)

2—Base Circle Diameter = Cosine Corrected PA × PD

EXAMPLE:

An involute spur shaper cutter of 10 DP, 20° PA and 40 Teeth

Given: Side relief angles, both = 2°
Face sharpening angle = 5°

Calculations: Nominal PD = $\frac{40}{10}$ = 4 inches

from 1, above

Tan Corrected PA = tan 20° + (tan 2° × tan 5°)
= .36397 + (.03492 × .08749)
= .36397 + .00305
= .36702
Corrected PA = 20° 09′ 14″

and: from 2, above

Cutter Base Circle Diameter
= Cos 20° 09′ 14″ × 4
= .93877 × 4
= 3.7551 inches

CALCULATION OF BASE CIRCLE DIAMETERS FOR HELICAL SHAPER CUTTERS

Formulas:

3—$$\text{Cutter PD} = \frac{\text{Number of Teeth}}{\text{NDP} \times \text{Cosine of Helix Angle}}$$

4—For both sides:
Tangent of Corrected NPA =
Tangent of Nominal NPA + (Tangent of Side Relief Angle × Tangent of Face Sharpening Angle)

5a—For the Uphill side: See figure 28.

$$\text{Tangent of the Corrected TPA} = \frac{\text{Tangent of Corrected NPA} \times \text{Cosine of Uphill Side Relief Angle}}{\text{Cosine (Helix Angle at Nominal PD} - \text{Uphill Side Relief Angle)}}$$

5b—For the Downhill side:

$$\text{Tangent of the Corrected TPA} = \frac{\text{Tangent of Corrected NPA} \times \text{Cosine of Downhill Side Relief Angle}}{\text{Cosine (Helix Angle at Nominal PD} + \text{Downhill Side Relief Angle)}}$$

6—For both sides:
Cutter Base Circle Diameter =
Cosine Corrected TPA × PD

EXAMPLE:

An involute helical shaper cutter of 10 NDP, 20° NPA, 40 Teeth and 23° RH helix angle with Normal sharpening

Given: Side relief angle, Uphill side = 2°
Side relief angle, Downhill side = 3°
Face sharpening angle = 5°
Normal sharpening angle = 23°

Calculation of Pitch Diameter from 3, above

$$\text{Cutter PD} = \frac{40}{10 \times \text{Cos } 23^\circ} = \frac{40}{10 \times .92050} = 4.3455 \text{ inches}$$

Calculation of Base Circle Diameter, Uphill side from 4, above

Tan Corrected NPA = tan 20° + (tan 2° × tan 5°)
= .36397 + (.03492 × .08749)
= .36702
Corrected NPA = 20° 09′ 14″ (Uphill side)

from 5a, above

$$\text{Tan Corrected TPA} = \frac{\tan 20^\circ\, 09'\, 14'' \times \text{Cos } 2^\circ}{(\text{Cos } (23^\circ - 2^\circ} = \frac{.36702 \times .99939}{.93358} = .39290$$

Corrected TPA = 21° 27′ (Uphill side)

and: from 6, above

Cutter Base Circle Diameter, Uphill side
= Cos 21° 27′ × 4.3455
= .93074 × 4.3455
= 4.0445 inches

Calculation of Base Circle Diameter, Downhill side from 4, above

Tan Corrected NPA = tan 20° + (tan 3° × tan 5°)
= .36397 + (.05241 × .08749)
= .36397 + .00459
= .36856
Corrected NPA = 20° 13′ 55″ (Downhill side)

from 5b, above

$$\text{Tan Corrected TPA} = \frac{\tan 20^\circ\, 13'\, 55'' \times \text{Cos } 3^\circ}{\text{Cos } (23 + 3)} = \frac{.36856 \times .99863}{.89879} = .40950$$

Corrected TPA = 22° 16′ 09″ (Downhill side)

and: from 6, above

Cutter Base Circle Diameter, Downhill side
= Cos 22° 16′ 09″ × 4.3455
= .92542 × 4.3455
= 4.0214 inches

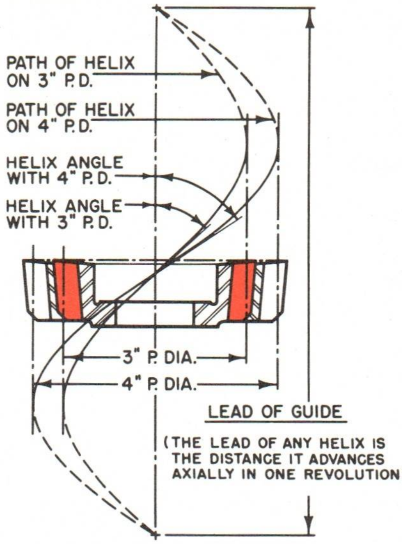


Figure 49—Relationships of helical guide and cutter.

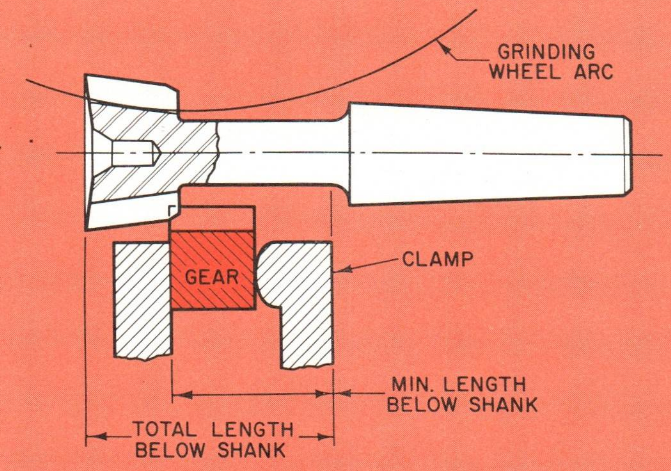


Figure 50—Shank type Shaper Cutter in relation to work piece and grinding wheel.

SHAPER GUIDES — For a single reduction set of helical gears, two guides, one RH and one LH, are required. The design of a single pair or small production lot of gears is frequently adjusted to use an available set of guides. Therefore, the principles involved in selecting the correct guide for a given gear must be clearly understood.

The helix angle of the cutter teeth and also the helix angle of the path of a cutter tooth as it is simultaneously reciprocated and revolved by the cutter spindle and guide must be the same as the helix angle of the gear teeth being shaped. The helix angle of the cutter tooth path depends on two factors: one, the cutter diameter and two, the lead of the guide. See figure 49.

The freedom of choice in regard to cutter diameter is limited to diameters giving a whole number of teeth ($PD = \frac{\text{No. of Teeth}}{\text{TDP}}$). Therefore, the helix angle of the gear being shaped must be changed, if necessary, to secure a whole number of teeth in the cutter and use an available guide. Of course, if new guides are to be obtained any desired helix angle can be cut on a gear with a given cutter diameter.

1—The lead of the shaper guide must be in the same ratio to the lead of the gear being cut as the ratio of the number of teeth in the cutter bears to the number of teeth in the gear.

$$\frac{\text{Lead of guide}}{\text{Lead of gear}} = \frac{\text{Number of teeth in Cutter}}{\text{Number of teeth in Gear}}$$

2—The lead of the guide must be the same as the lead of the cutter.

3—Determining the suitability of a given guide for cutting a given helical gear.

Given a guide with lead of 25.904 inches.
Gear to be cut: 14 Tooth with a lead of 15.839 inches.

Theoretical number of teeth in cutter

$$= \frac{14 \times 25.904}{15.839} = 22.896 \text{ Teeth}$$

The nearest possible cutter would have 23 Teeth and for a 23 Tooth cutter the correct guide would have a lead of $\frac{23}{14} \times 15.839$ or 26.021 inches.

If the 23 Tooth cutter were used with the guide having a lead of 25.904 inches, the lead error per inch of gear face width would be,

$$\frac{26.021 - 25.904}{26.021} = .0045$$

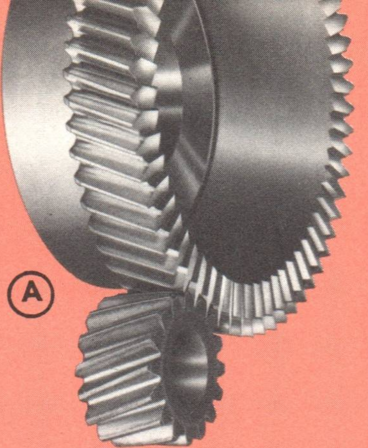
This error is too great and either the lead of the gear being cut must be changed to 15.769 or a new guide secured.

SELECTION OF SHANK SIZE AND LENGTH — Since the grinding wheel used for tooth form generation must clear the shank on shank type Shaper Cutters, see figure 50, the large end taper diameter should be kept in proportion to the Pitch Diameter of the cutter. For example, a cutter with a Pitch Diameter of 5/16 should preferably not be made on a 1.062 or .700 size shank. The #1 Morse or #2 Jarno tapers (with an adaptor, if necessary, to use in a large shaper) will result in a shorter, more rigid cutter, one less likely to break and one requiring less length for grinding wheel clearance.

The length below shank, see figure 50, must be great enough to clear the grinding wheel arc and also great enough to clear the work

(Continued on page 24)

TYPICAL DESIGN VARIATIONS OF GEAR SHAPER CUTTERS AND HERRINGBONE CUTTERS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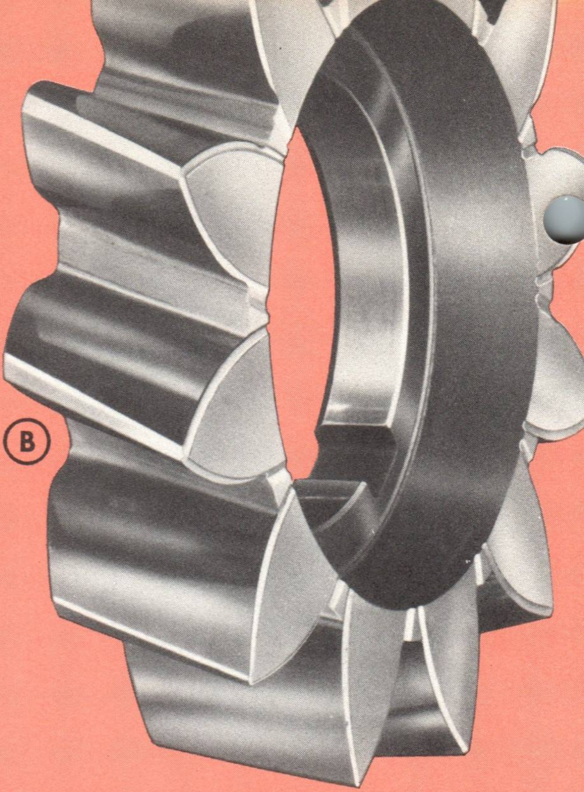
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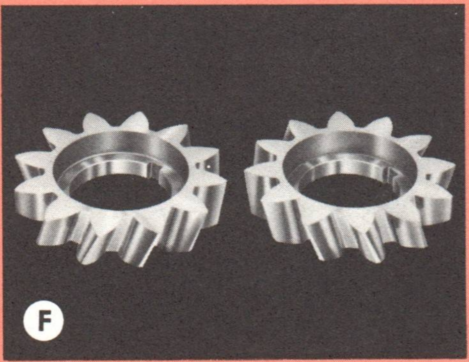
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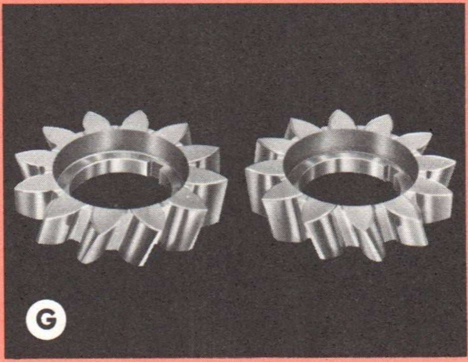
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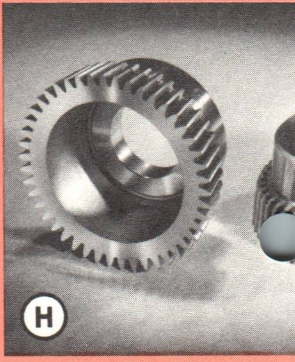
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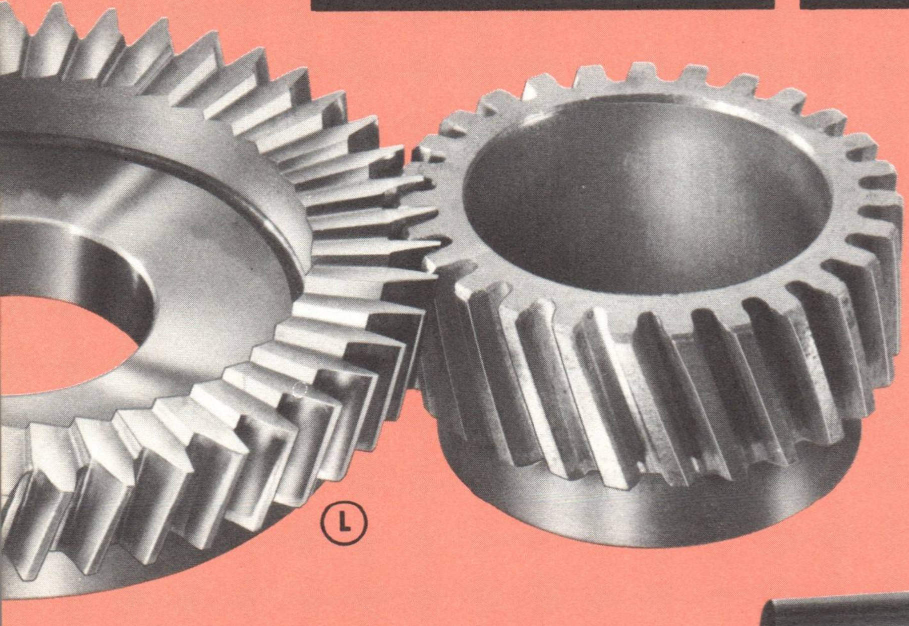
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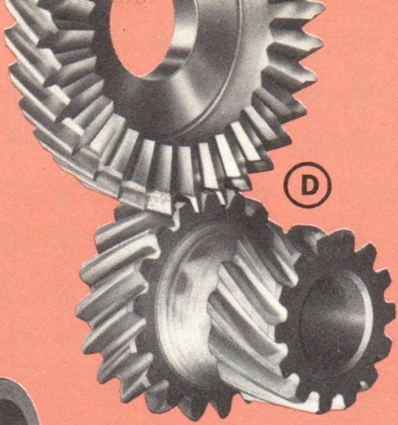

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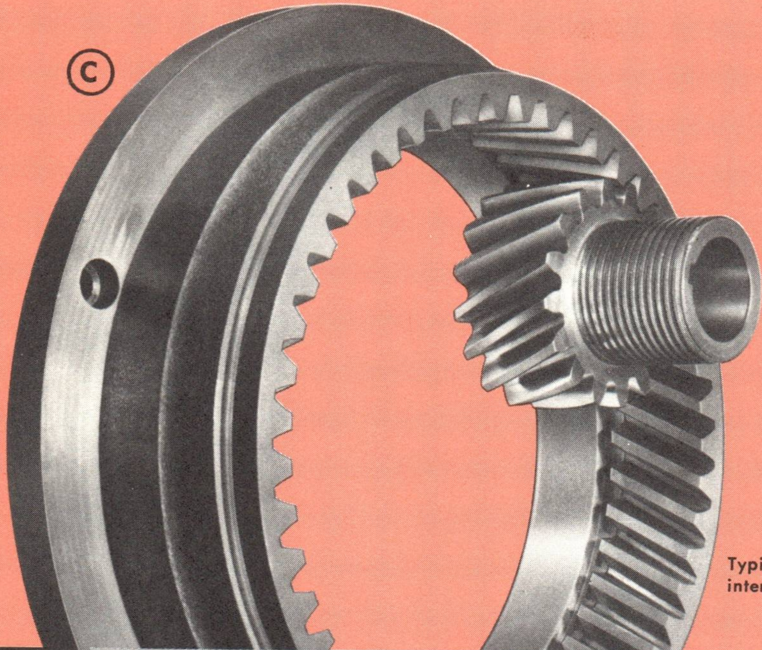
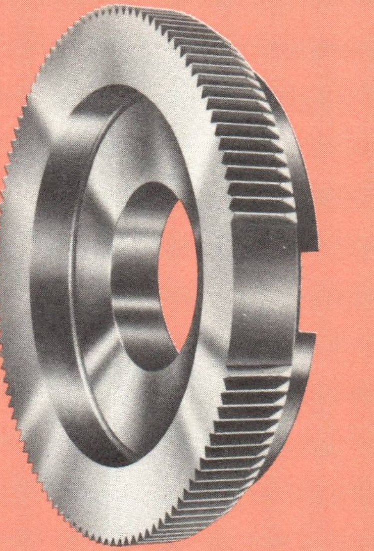


C

Typical gear Shaper Cutter application—internal gear and mating pinion.



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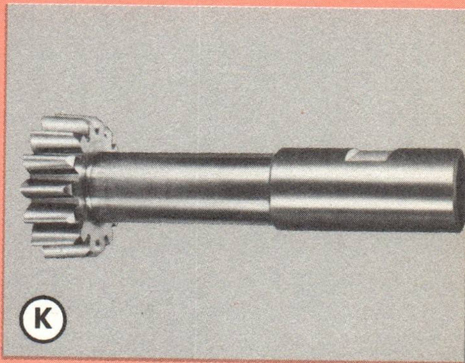

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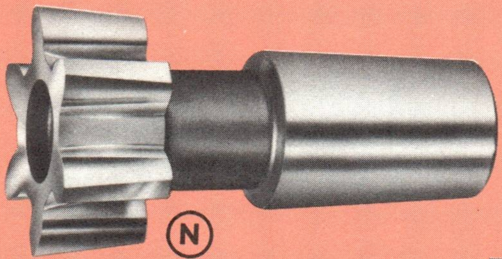

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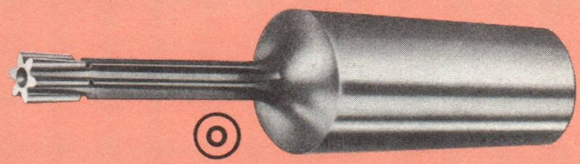

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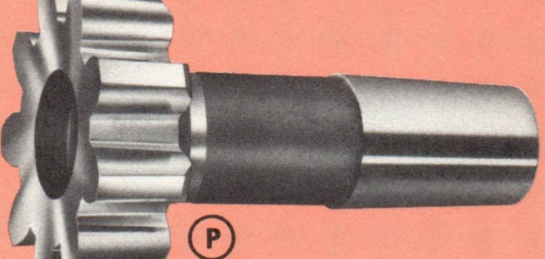

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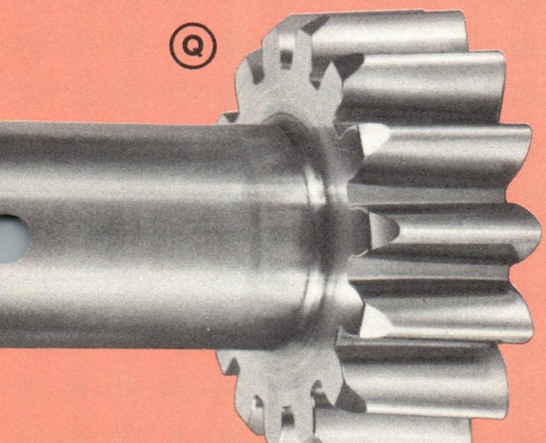

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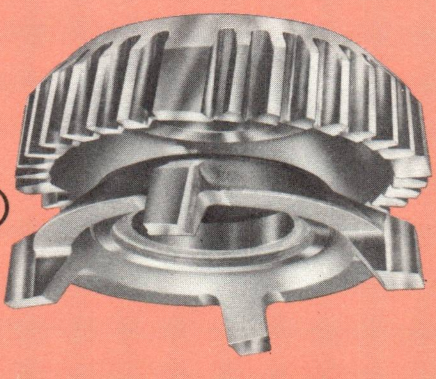


R

and work clamp (or holding device) at the end of cutter life. In ordering, the best practice is to specify only the necessary length for work and fixture clearance. (We suggest the term, "Minimum length below shank.") The manufacturer may then increase this if required for grinding wheel clearance and add the length of usable cutter to get the total length below shank.

DISK OR DEEP COUNTERBORE CUTTERS? — A Deep Counterbore Type cutter may be required: See figure 14, page 9.

1—To extend the "reach" of the spindle. That is, the cutting face is placed at a greater distance from the spindle end than in the case of a Disk Type cutter.

2—To clear a raised hub or other obstruction in the center of an internal gear.

3—To maintain the retaining nut back of the cutting face throughout the life of the cutter in order to clear a shoulder on the part.

RATIO BETWEEN CUTTER AND GEAR DIAMETERS — When gear Shaper Cutters are made with gaps, roughing and finishing sections, a space omitted, thick and thin teeth or other such features, the number of cutter teeth must have an integral ratio to the total number of teeth in the gear or to the number of gear teeth in the repeated pattern on the gear periphery.

It is possible, when only one section of the cutter periphery is used to complete the gear, to base the gear Shaper Cutter design on a fractional number of teeth in the cutter.

COMBINATION ROUGHING AND FINISHING CUTTER – If a Shaper Cutter for external gears is more than twice as large as the gear being cut, it may be made with a roughing section and a finishing section separated by gaps, one of which may be used as a loading gap. If sufficiently large in relation to the gear, the cutter may be made with three sections: Roughing, Semi-finishing and Finishing sections.

In addition, the gaps between sections make it possible to thin the end teeth on the finishing section and thus avoid the cutting of one gear tooth space slightly wider than the rest at the point of overlapping action.

SHAPING OF INTERNAL GEARS – Generally, internal gears are cut by the Shaping method. Three techniques are available: Side Trimming from a roughed out blank, Off-set generating from a roughed out blank, and full generating. Since only the latter method is widely used, the first two will be passed over. In the same way the 14½° PA system will be ignored because of its decreasing use in new designs.

Illinois Tool Works gear engineers will be glad to discuss with customers any such phases of Shaper Cutter application not covered in this booklet.

The designing of an internal gear and its pinion requires more careful, detailed analysis than is usually necessary for external gears. Checks must be made for Involute Interference, Assembly Interference, and Contact Ratio. Before "freezing" the gear design the suitability of the design for the Shaping Process should be considered. Small changes in the gear design which will not impair the action, may be necessary or desirable for application of the Shaping Process.

For this discussion it will be assumed that the mating gears have been properly designed for assembly and satisfactory operating characteristics and the proper cutter is to be designed, or selected from those available.

The following five sources of difficulty in Shaping the Internal gear must be considered in the cutter selection or design:

1—Can the Shaper Cutter be fed radially to depth without "Feed Fouling?" Figure 51.

2—Will there be sufficient clearance to prevent "Rubbing" due to the relieving action of the machine? Figure 52.

3—Is the Fillet produced by the cutter small enough to prevent "Fillet Interference?" Figure 27, page 12.

4—In the generating action will the flanks of the cutter teeth produce excessive "Trimming?" Figure 53.

5—In the generating action will the tips of the cutter teeth produce "Tip Fouling?" Figure 54.

These rules for cutter selection are necessarily general in nature, but may be helpful in the avoidance of trouble:

A – *A 10-Tooth Shaper Cutter is usually considered the smallest practical cutter for internal gears. Sometimes, for specific applications, cutters with as few as 5 teeth can be designed.*

B – *Because the addendum of the gear Shaper Cutter is greater than the addendum of the pinion, a safe general rule for selection of the cutter diameter is to make the number of teeth in the Cutter equal to or slightly less than the number of teeth in the pinion. The design of the internal gear and the pinion may be such as to allow a cutter either larger or small-*

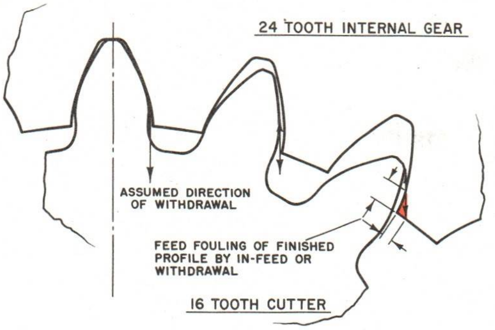

24 TOOTH INTERNAL GEAR
ASSUMED DIRECTION OF WITHDRAWAL
FEED FOULING OF FINISHED PROFILE BY IN-FEED OR WITHDRAWAL
16 TOOTH CUTTER

Figure 51—Feed fouling occurring when gear Shaper Cutter is fed radially to depth.

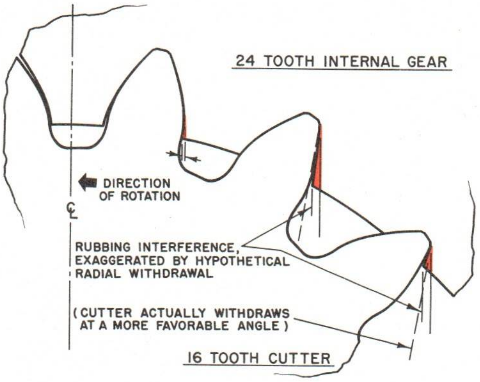

24 TOOTH INTERNAL GEAR
DIRECTION OF ROTATION
℄
RUBBING INTERFERENCE, EXAGGERATED BY HYPOTHETICAL RADIAL WITHDRAWAL
(CUTTER ACTUALLY WITHDRAWS AT A MORE FAVORABLE ANGLE)
16 TOOTH CUTTER

Figure 52—Rubbing interference between Shaper Cutter and gear due to relieving action of machine.

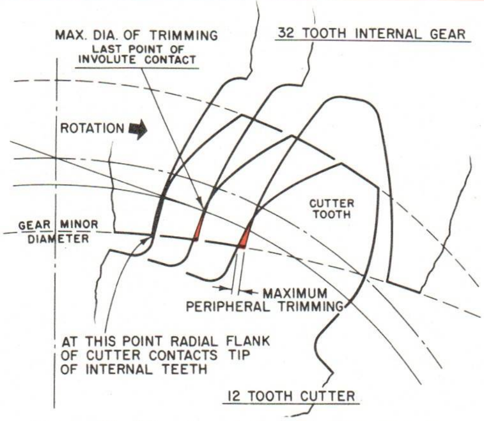

MAX. DIA. OF TRIMMING
LAST POINT OF INVOLUTE CONTACT
32 TOOTH INTERNAL GEAR
ROTATION
CUTTER TOOTH
GEAR MINOR DIAMETER
MAXIMUM PERIPHERAL TRIMMING
AT THIS POINT RADIAL FLANK OF CUTTER CONTACTS TIP OF INTERNAL TEETH
12 TOOTH CUTTER

Figure 53—Trimming of internal gear teeth by cutter tooth flanks during generating action.

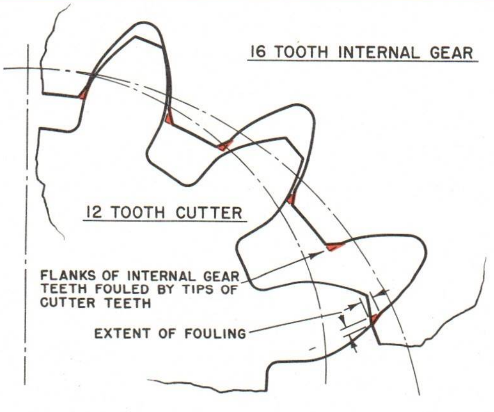

16 TOOTH INTERNAL GEAR
12 TOOTH CUTTER
FLANKS OF INTERNAL GEAR TEETH FOULED BY TIPS OF CUTTER TEETH
EXTENT OF FOULING

Figure 54—Tip fouling during generating action.

er than the pinion, and, if there is no interference, the use of a cutter larger than the pinion usually results in smoother operation of the pinion and internal gear.

C – *The smaller the cutter in relation to the internal gear diameter the greater the danger of creating too large fillets in the gear.*

D – *The smaller the cutter in relation to the internal gear diameter the greater the danger of Trimming by the cutter tooth flanks.*

E – *The larger the cutter in relation to the internal gear diameter the greater the danger of "Feed Fouling."*

F – *Standard cutters may not be suitable since the Shaper Cutter diameter cannot be "Oversize" for some applications.*

TABLE I shows the practical range of cutter and pinion sizes for internal gears from 22 to 80 Teeth. In some parts of the range shown full involute tooth depth is not secured on the internal gear, but the contact ratio is still sufficient for proper gear action. In borderline cases and applications outside of the tabulated range, graphical or mathematical analysis of the Shaper Cutter action may be necessary. Illinois Tool Works gear engineers are always ready to help customers in this connection.

TABLE I

Size Guide for Selection of Shaper Cutters
For Internal Gears
All values in number of teeth

Internal Gear	20° Stub			20° Full Depth			25° Full Depth		
	Max. for Cutter	Max. in Pinion	Min. for Cutter	Max. for Cutter	Max. in Pinion	Min. for Cutter	Max. for Cutter	Max. in Pinion	Min. for Cutter
22	10	14	10	—	—	—	10	16	10
24	11	16	11	10	14	10	11	18	10
26	12	18	11	10	16	10	12	20	10
28	13	20	12	11	18	11	13	22	11
30	14	22	13	12	20	12	14	24	11
32	16	24	14	14	22	13	16	26	12
36	19	28	16	16	26	15	19	30	13
40	22	32	18	19	30	16	22	34	14
44	25	36	19	22	34	18	25	38	15
48	28	40	21	25	38	20	28	42	16
52	32	44	22	28	42	21	32	46	17
60	38	52	24	35	50	23	38	54	18
70	47	62	26	43	60	26	47	64	19
80	56	72	28	51	70	28	56	74	20

Note: Cutter size should not exceed pinion size. See item "B" page 24.

INDICATING BANDS—All cutters ordered as "Precision Tolerance" are supplied with a ground indicating band, and "Commercial Tolerance" cutters can be supplied on request with an indicating band as an extra. This indicating band is a narrow, ground cylindrical surface adjacent to the teeth. See figure 55, page 27 and figure 18, page 9.

USE OF INDICATING BANDS – Indicating Bands allow an over-all check of the accuracy of the spindle, the spindle mounting surfaces, and the locating surfaces of the cutter. Also, by proper interpretation and correlation of actual cutter Pitch Diameter runout and actual indicating band runout, the actual indicator reading resulting in minimum cutter Pitch Diameter runout as mounted may be marked on the band for very rigorous product requirements.

DEPTH OF SHAPED GEAR TEETH – To reduce the hazard of accidental fillet interference, it is standard practice to increase the clearance on coarse pitch shaped gears. Instead of $\frac{.157}{DP}$ it is customary to use $\frac{.250}{DP}$ for the clearance (difference between addendum and dedendum). This results in a whole depth (WD)* of $\frac{2.250}{DP}$. With establishment of standards for fine pitch gears this need for clearance was also recognized and Shaper Cutters for gears of 20 DP and finer are made to cut a whole depth of $\frac{2.200}{DP} + .002$. Herringbone Gear Shaper Cutters are made to cut a whole depth (WD) of $\frac{1.9}{TDP}$.

PRE-SHAVE SHAPER CUTTERS – Pre-Shave Shaper Cutters are usually made to cut a whole depth of $\frac{2.400}{DP}$ and are made with basic tooth thickness. Thus, the backlash obtained is equal to the stock removed in shaving. More backlash is usually obtained by cutting to a slightly greater depth in shaping.

ROUGHING SHAPER CUTTERS – Shaper Cutters for roughing cuts are not necessary for gears finer than 12 DP and are infrequently used for pitches finer than 6 DP. Standard practice is to make roughing Shaper Cutters to leave $\frac{.150}{DP}$ stock on tooth thickness.

THE INVOLUTE SPLINE STANDARD ASA B5.15—Shaper Cutters are widely used for cutting both internal and external involute splines and all the principles discussed in connection with Shaper Cutters for gears apply with equal force to Shaper Cutters for involute splines.

The standard permits no modification or trimming of the involute between the minor diameter and the form diameter on the internal spline, or between the major diameter and the form diameter on the external part, but it is sometimes unavoidable in small diameter internal splines cut by shaping.

Internal Major Diameter Fit splines cut by Shaper Cutters may, in some cases, violate this Standard in the specification for maximum fillet height at the major diameter. Reasonable control of the chamfer height, and of the eccentricity of the chamfers, major diameter, and pitch diameters on the external spline will eliminate difficulty.

In the 1960 revision of this Standard the same violation of the maximum fillet height at the major diameter of an internal spline may occur in some sizes of Flat Root Side Fit and Major Diameter Fit Splines. Small adjustments in the specifications for some sizes may be necessary to suit the Shaping method. Strict adherence to all specifications of the 1960 revision requires a review of tooling purchased to previous standards.

INVOLUTE APPLICATIONS OTHER THAN GEARS AND SPLINES—Involute form Shaper Cutters are frequently used in the production of worm threads, rack teeth and clutch teeth. These applications require either special shaping machines or the addition of attachments to a standard gear shaper. The general principles governing cutter design, construction, and use are the same as those for gear applications. When used for Side Trimming in the production of clutches, a keyway or drive slot is necessary to secure a positive rotation in the cut.

NON-INVOLUTE APPLICATIONS—Shaper Cutters for roller chain sprockets, see figure 23, page 9, although non-stock items can be readily supplied to standard proportions.*

**WD is now the standard industry symbol (abbreviation) for Whole Depth. It is identical in meaning and usage with the now obsolete expression (D+F).*

**American Standard ASA B 29.1.*

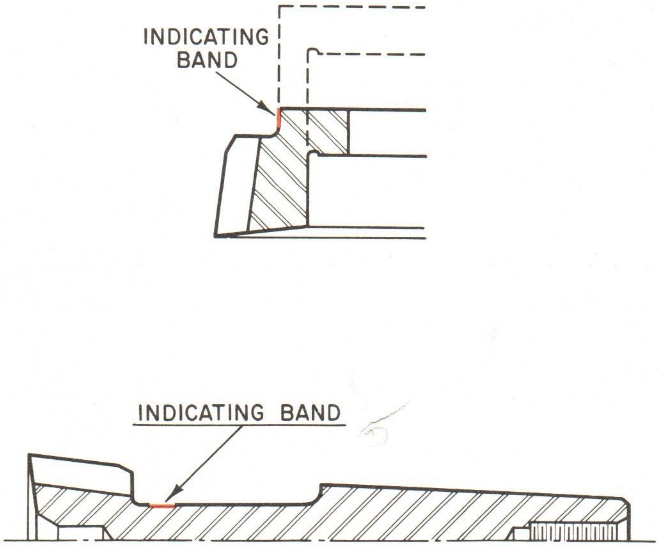


Figure 55—Location of indicating bands.

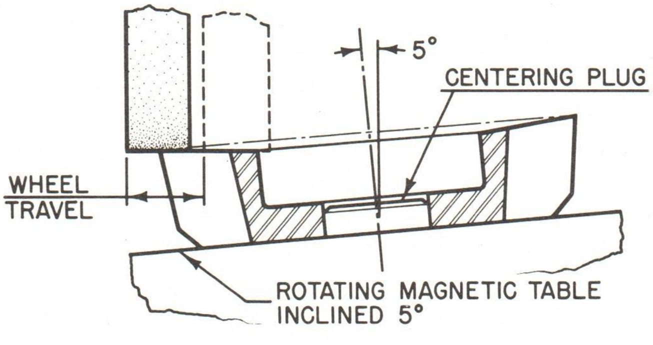


Figure 56—Sharpening Spur Gear Shaper Cutter.

SHARPENING SHAPER CUTTERS AND HERRINGBONE CUTTERS – Illinois Tool Works' Shaper Cutters are ground to rigorous standards of accuracy and surface finish. Because of the low side relief angles inherent in Shaper Cutter design, the flank surfaces of all cutter teeth are finished to exceptional standards for smoothness. It is just as important because of the low rake (face sharpening angle) and the need for free chip flow to have a finely finished face on the Shaper Cutter. For superior performance the user will find that care to obtain the best possible finish in face sharpening will pay dividends in longer cutter life.

In general, Shaper Cutters should not be used beyond a point where .005 on fine pitch cutters, graduated to .015 on coarse pitch cutters need be ground from the face to restore keen cutting edges.

While wet grinding equipment is not always available, the advantages of a copious flow of coolant in producing finely finished surfaces on high speed steel tools such as Shaper Cutters is well recognized.

The sharpening of Spur Shaper Cutters is relatively simple. A surface grinder with a rotary table – or a rotary table surface grinder – see figure 56, is necessary and the rotary magnetic chuck is tipped to the face sharpening angle (usually 5°). On Illinois Tool Works Spur (and Helical) Cutters any face sharpening angle other than 5° is marked on the cutter. This face sharpening angle must be maintained to avoid undesirable changes in the tooth form being cut.

Due to the varying area of contact as tooth and space on a Shaper Cutter alternately pass under the grinding wheel a high and low or wavy pattern may be produced on the face of the cutter unless a rigid machine with a rigid spindle is used for sharpening.

It is recommended that sharpening be done in two stages: *roughing* with a vitrified aluminum oxide wheel of about 60 grain size, H grade, and free cutting grain type and structure to leave about .001 to .002 for finishing; next, *finishing* with a resinoid or shellac bond silicon carbide wheel of about 400 grain size in a soft grade and free cutting type.

Some users may find it possible with the proper wheel, refined techniques, a rigid grinding machine, a rigid grinding spindle,

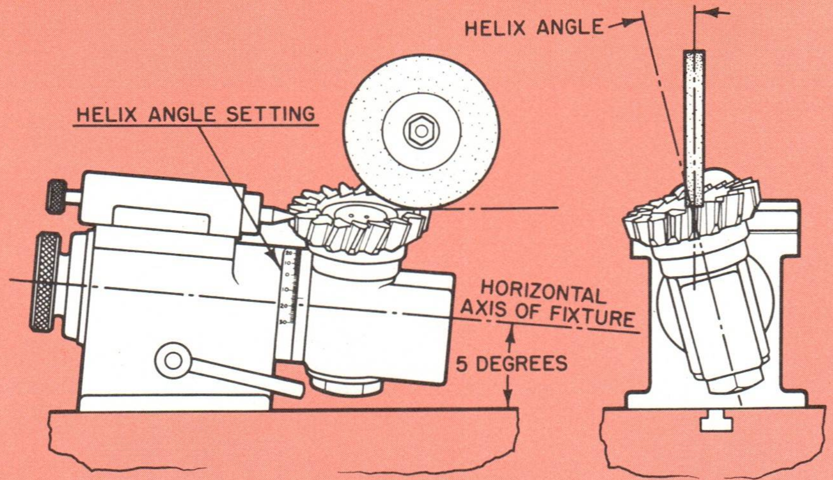


Figure 57—Fixture for sharpening Helical Gear Shaper Cutter.

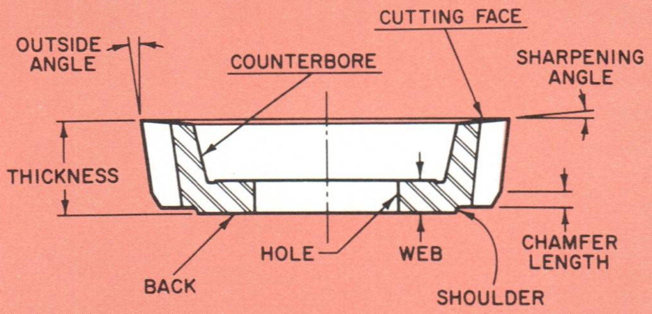


Figure 58—Disk type Shaper Cutter.

balanced grinding wheels, smooth driving mechanisms and sensitive, accurate downfeed to achieve a good final finish without burn using a single grinding operation. This should not be undertaken on a casual basis, however, because of the importance of the surface quality on the face.

In sharpening small Spur Shaper Cutters of the shank and hub types the grinding wheel must be reduced in diameter or else the sweep of the grinding wheel will create a "bowl" shaped face grind instead of a true conical surface. If this occurs, the tooth form cut will not be accurate.

In the case of Helical Shaper Cutters a more elaborate set-up is required for sharpening. A hand indexed fixture which can be used on any standard reciprocating table surface grinder is illustrated in figure 57. Automatic equipment is also available. Unfortunately, a lower standard of surface finish on the tooth faces of Helical Shaper Cutters must be accepted because the grinding is by a fixed position, straight through, reciprocating motion. It is usual to specify free cutting aluminum oxide wheels varying from 90 grain size, I or J grades for coarse pitches to 150-180 grain size in J or K grades for fine pitches. Since one edge (corner) of the wheel face is cutting, the wheel must be dressed frequently to avoid a radius sweeping down on to the face where it would distort the tooth profile. As on Spur cutters any face sharpening angle other than 5° is marked on the cutter. In addition any deviation from "normal" sharpening (such as a 15° angle on a 23° Helix Angle Cutter) will be shown by marking the correct grinding angle on the cutter.

On Helical Cutters it is very important to have a uniform "spark-out" on all teeth to hold all corresponding points on the teeth in the same plane and on semi-topping cutters it is important that the corner of the grinding wheel cuts to the center of the cutter tooth space.

In sharpening Herringbone Cutters the first operation is to grind the entire top face

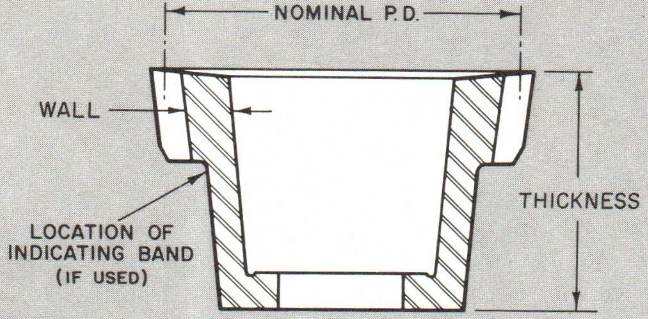


Figure 59—Deep Counterbore Type Shaper Cutter.

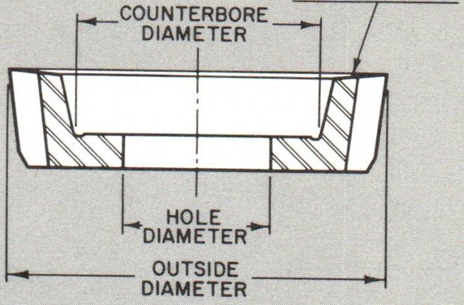


Figure 60—Flat back disk type Shaper Cutter.

flat (0° face sharpening angle) to remove the wear land. In this operation the stock removed must be equal on both cutters in a set since the diameters must be kept equal. The second operation is to grind the "grooved" cutting edge, and the third operation is to grind the "dubbed" cutting edge, following the involute to produce the full Lip Sharpening characteristic of these cutters. The "grooved" cutting edge (which is on the uphill side) should be slightly higher than the "dubbed" edge since it clears the gear tooth apex at the end of the cutting stroke. See figures 15 and 16, page 9, for the cutters before and after Lip Sharpening.

STEEL AND METALLURGY – Illinois Tool Works' Shaper Cutters are made from high speed steel purchased to rigid specifications. Forgings are made in our own forge shop to refine the grain structure for greatest strength. See inside front cover. The heat treatment to secure a final hardness of Rc 64-66 is by the best techniques and subject to the finest controls available.

Where the application requires it, special purpose or super high speed steels will be recommended.

SURFACE TREATMENTS – Of the many surface treatments available for improving the life of high speed steel Shaper Cutters the one which has best stood the test of time is Nitriding (also sometimes called Cyaniding). This simple, economical surface treatment is sometimes distinguished by the use of trade mark designations, and sometimes combined with the Steam-Homo treatment or vapor blasting. Its proper use, however, requires rigid control over cleanliness, time, and temperature to secure the maximum benefit.

Nitriding makes the cutting edges more brittle and therefore, more susceptible to chipping. Because of this, its application to Shaper Cutters cannot be made indiscriminately, and we will be pleased to cooperate in exploring its advantages on a given application.

Gear Shaper Cutter Nomenclature

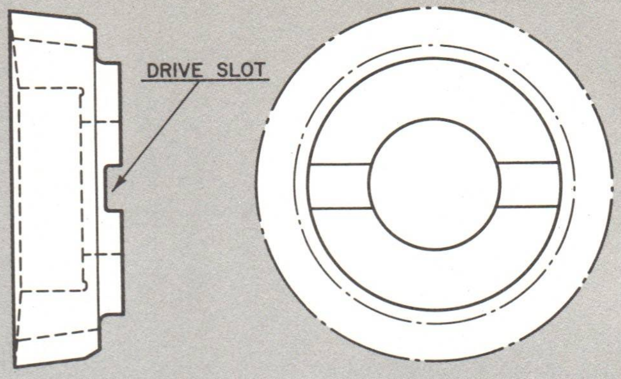


Figure 61—Disk type Shaper Cutter with Drive Slot.

GEAR SHAPER CUTTER—A cutting tool which is basically a gear with the teeth relieved to create cutting edges on the face.

(Arranged Alphabetically)

APPROACH—An intentional outward deviation from the true involute form at the base of a Gear Shaper Cutter tooth which produces Tip Relief on the gear tooth. See TANGENT APPROACH and CONSTANT APPROACH.

ASSEMBLY INTERFERENCE—Interference between an internal gear and its pinion which prevents meshing of the two by assembly in a radial direction. Axial assembly of the parts may be possible and correct operation possible even though radial assembly cannot be made.

BACK — That surface of the cutter opposite the cutting face. It is usually, but not always the mounting face of the cutter. It may extend as one flat surface from edge to edge of the cutter or be relieved so that its diameter is reduced. See figure 58, page 28.

CHAMFER—(1)—A chamfer, usually at 30° to 45° from the cutter axis, turned or ground on the backs of the cutter teeth. Its length is measured in the axial direction. See fig. 58. (2)—The tip chamfer produced on a gear tooth by the Ramp on a Shaper Cutter. Its length is measured in the radial direction. See page 16 and figure 41, page 17.

COMBINATION ROUGHING AND FINISHING GEAR SHAPER CUTTER—A gear Shaper Cutter with a number of roughing teeth on one part of the periphery and a number of finishing teeth on another part of the periphery to enable roughing and finishing cuts to be taken on a gear at one set up.

CONSTANT APPROACH—An approach consisting of a surface whose intersection with the involute tooth surface is a curved line placed to give an approximately constant length of involute on the Shaper Cutter tooth as the face is sharpened back. See figure 36, page 15.

COUNTERBORE — An enlargement of the hole at the cutter face which receives the retaining nut and reduces the face area to facilitate sharpening. It may be straight or tapered, and its depth may be such as to clear an obstruction or ensure that the retaining nut will clear the work at the end of cutter life. See figure 58.

CUTTING FACE—The front or forward face of the cutter, against which the chips impinge.

DEEP COUNTERBORE TYPE SHAPER CUTTER—A Shaper Cutter similar to the Disk type but increased in over-all axial length to secure a deep counterbore so that at the end of the sharpening life the mounting nut will not strike the work or fixture. See figure 59, page 29.

DEPTH OF CUT—The radial distance that the cutter teeth are engaged with the work.

DISK TYPE SHAPER CUTTER—The most common body type for gear Shaper Cutters. It is an arbor-type cutter in the form of a disk with a central mounting hole which is usually

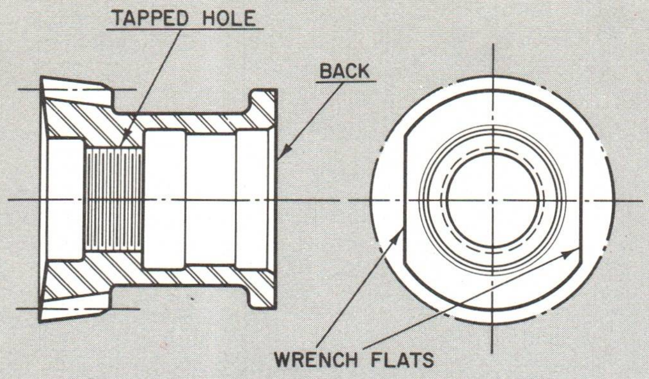


Figure 62—Hub Type Shaper Cutter.

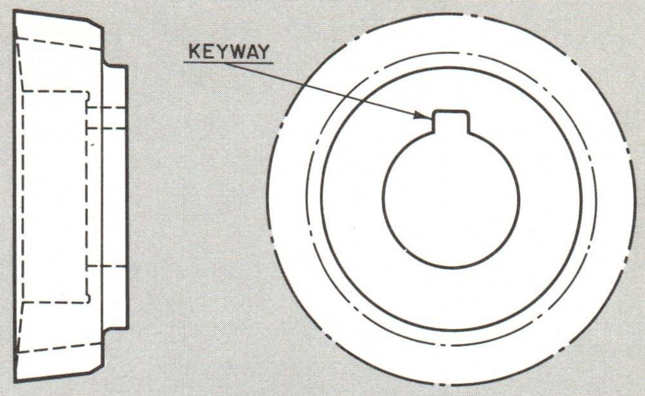


Figure 63—Disk type Shaper Cutter with keyway.

counterbored. It resembles a gear in having straight or helical teeth around its periphery which intersect the forward face of the disk to form cutting edges. See figure 58.

DISK TYPE SHAPER CUTTER WITHOUT SHOULDER — A modification of the Disk Type sometimes referred to as Flat Back Style. This style is sometimes specified so that a backing plate can be used to support the teeth near the end of life. See figure 60, page 29.

DOWNHILL SIDE — The leading flank of a cutter tooth on a RH Helical Gear Shaper Cutter when viewed from the face and rotated counterclockwise. See figure 44, page 17. The trailing flank of a cutter tooth on a LH Helical Gear Shaper Cutter when viewed from the face and rotated counterclockwise.

DRIVE SLOT — A slot (sometimes called a "Clutch" keyway) in the back of a Shaper Cutter to secure a positive rotational drive or maintain a definite angular location of the cutter. It may be precisely located with respect to a tooth or a space. See figure 61.

DUB-OFF—An expressive shop term indicating

1—A reduction of rake along a cutting edge made by grinding a narrow band along the Downhill cutting edge at an angle to the flat face on Herringbone cutters, or,

2—An undesirable removal of metal from a surface adjacent to a cutting edge so that the desired cutting geometry is destroyed, or,

3—An undesirable removal of metal from the flanks of gear teeth (in excess of that called Trimming) at the minor diameter of an internal gear.

FEED FOULING—Undesirable cutting by the extreme tip (corner) of the Shaper Cutter tooth as the Cutter is fed radially to depth in an internal gear. See figure 51, page 25.

FILLET—The generated curve joining root and flank at the base of the gear tooth. It is at the minor diameter on an external gear and at the major diameter on an internal gear. See figure 27, page 12 and figure 32, page 14.

FILLET INTERFERENCE—Interference between mating gears at the fillet in one or both gears. It is due to the generated fillet being too large or extending outward too far from the Gear tooth root. See figure 27, page 12.

FLANGE—An enlarged section, close to the size line on a taper shank, sometimes used to secure a desired angular location of a Taper Shank Shaper Cutter. See figure 65, page 34.

FOULING — See TIP FOULING and FEED FOULING.

GAP—A portion of the periphery of a gear Shaper Cutter where teeth have been removed or omitted. See Cutter E, page 23.

GAP TYPE GEAR SHAPER CUTTER — A gear Shaper Cutter having several consecutive teeth removed at one or more points on the periphery to form one or more gaps. The gaps thus formed may be for the purpose of facilitating the loading of gears or for the purpose of separating roughing and finishing sections on the periphery of the cutter. See Cutter E, page 23.

GUIDE—The machine sub-assembly which gives a rotational movement to a helical Shaper Cutter as it is moved in the axial direction, and therefore imparts a helical movement of specified lead to the Shaper Cutter. For spur Shaper Cutters, guides are straight.

HELICAL GEAR SHAPER CUTTER—A Shaper Cutter with involute profile teeth which are formed in uniform helical paths about the cutter axis. See Cutter D, page 23.

HELIX ANGLE—The inclination of the tooth on a helical gear Shaper Cutter. It is measured from an axial plane at the pitch diameter of the cutter.

HERRINGBONE CUTTERS — (sometimes referred to as Sykes Cutters) Shaper Cutters designed especially for operating without a clearance groove at the end of the stroke and therefore, capable of cutting solid, continuous tooth, double helical gears (called Herringbone gears). Such cutters are made in matched pairs, of equal diameter, and have a special "Lip Sharpening" on the face. See Cutter B, page 22.

HOLE—The axial hole in a shaper cutter which centralizes the cutter on the shaper spindle. See figure 58, page 28.

HUB TYPE SHAPER CUTTER—A style of cutter adaptable particularly to intermediate diameters, between those suitable for Shank or Disk types. Sometimes specified for small diameters since a Hub Type Shaper Cutter can be mounted on a machine spindle having no taper hole without the use of an adaptor. See figure 62, page 31.

INDICATING BAND — A narrow cylindrical reference surface ground concentric with the axis of the cutter so that the runout can be checked as mounted. See figure 55, page 27.

INNER FACE—The bottom surface of the counterbore. It is accurately ground parallel to the back as a bearing surface for the retaining nut. See figure 28, page 13. It may sometimes be the mounting face.

INTERFERENCE — See ASSEMBLY INTERFERENCE, FILLET INTERFERENCE, TIP FOULING, FEED FOULING and RUBBING.

KEYWAY—A keyway in the hole of a Shaper Cutter to provide a positive rotational drive or maintain a definite angular location of the cutter. It may be precisely located with respect to a tooth or a space. See figure 63, page 31.

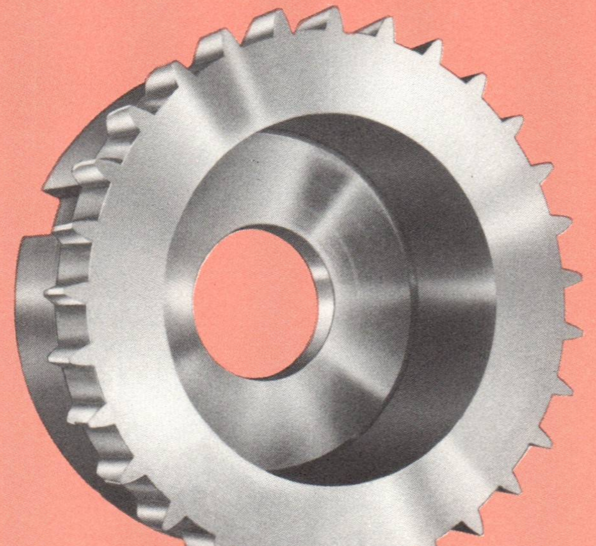


Figure 64—A Side Trimmer for cutting involute form internal clutch teeth.

LEAD—The axial advance of a cutter tooth, gear tooth, or tool element in making one complete turn about its axis. See figure 49, page 21.

LEFT HAND CUTTER—A Shaper Cutter whose helical teeth twist away from the observer in a counterclockwise direction. A Left Hand Cutter is used to cut Right Hand helical external gears and Left Hand helical internal gears.

MODIFICATION—Any deliberate departure from true involute form. Where they exist, due to design and manufacturing necessity, radial flanks on a cutter tooth are not considered a modification.

NOMINAL PITCH DIAMETER — The basic pitch diameter of a Shaper Cutter. It is equal to

$$\frac{\text{Number of Teeth}}{\text{Diametral Pitch}}$$

in the case of Spur Cutters and equal to

$$\frac{\text{Number of Teeth}}{\text{Transverse Diametral Pitch}}$$

in the case of Helical and Herringbone Shaper Cutters.

NORMAL SHARPENING—Sharpening of the individual faces of the cutter teeth on a Helical Shaper Cutter to an angle perpendicular to the basic helix of the teeth. See figure 26, page 11, and figure 44, page 17.

OFF-NORMAL SHARPENING — Sharpening of the individual faces of the cutter teeth on a Helical Shaper Cutter to an angle not the same as the helix of the teeth. See figure 47, page 19.

OPERATING DIAMETER—The Pitch Diameter of the Shaper Cutter in operating relationship to the gear being cut. It is twice the radial distance from the center of the cutter to the intersection point of the line of action and the line of centers. It may be greater or less than the Nominal Pitch Diameter. See figure 27, page 12.

OUTSIDE ANGLE — The cone angle of the peripheral surface measured with respect to the axis. It is the relief angle of the peripheral surface of the Shaper Cutter tooth. See figure 58, page 28.

OUTSIDE KEYWAY—A Keyway in the shoulder of a Shaper Cutter to secure a positive rotational drive or maintain a definite angular location of the cutter. It may be precisely located with respect to a tooth or a space. See figure 64.

OVERSIZE—The amount, at a specified point in its life, that the operating diameter of a Gear Shaper Cutter is larger than the Nominal Pitch Diameter.

PROTUBERANCE—A modification of a Gear Shaper Cutter to produce undercut on the flank of a gear tooth near the base of the gear tooth. It consists of an outward deviation from the involute cutter tooth profile near the tip and it produces clearance at the base of the gear tooth for the tip of the tooth on a shaving cutter or clearance for the edge of a grinding wheel. See figure 42, page 17.

RADIAL FLANK—A plane surface at the base of a Spur Gear Shaper Cutter tooth whose trace in a transverse plane is substantially radial. See figure 32, page 14.

RADIAL HEIGHT OF CHAMFER—See dimension "B" in figure 41, page 17.

RAMP—A cutting surface diverging at a considerable angle from the involute at the base of a Shaper Cutter tooth to produce a chamfer on the tip of a gear tooth. See figure 39, page 16.

RIGHT HAND CUTTER — A Shaper Cutter whose helical teeth twist away from the observer in a clockwise direction. A Right Hand Cutter is used to cut Left Hand helical external gears and Right Hand helical internal gears. See Cutter D, page 23.

ROLLING DIAMETER — See preferred term OPERATING DIAMETER.

ROOT CLEARANCE—Depth of cutter teeth minus depth of cut in work gear.

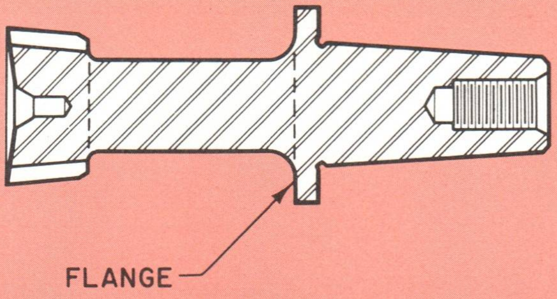


Figure 65—Shank Type Shaper Cutter with Flange.

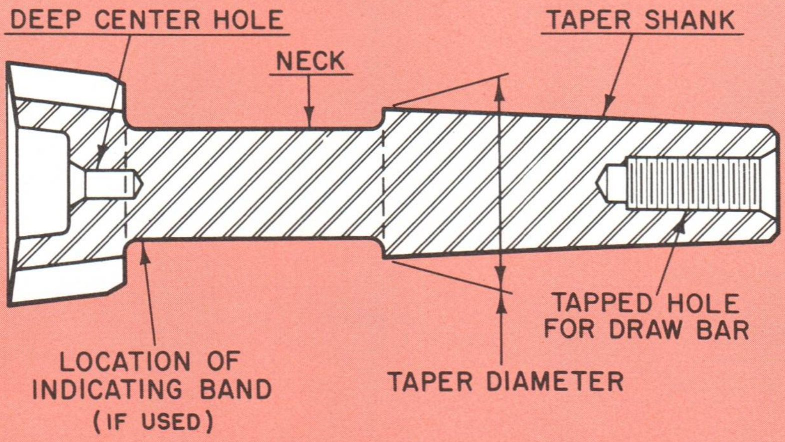


Figure 66—Shank Type Shaper Cutter.

RUBBING—Interference between some part of the Shaper Cutter tooth and the gear being cut on the return (non-cutting) stroke of the Shaper. Adjustment of the relieving mechanism may eliminate this interference. Design of the internal gear, and cutter must allow the necessary clearance for the relieving motion. See figure 52, page 25.

SEMI-TOPPING SHAPER CUTTER—A Shaper Cutter with a Ramp which produces a tip chamfer on the gear tooth.

SHANK TYPE SHAPER CUTTER — A Shaper Cutter with an integral taper or straight shank which may seat directly in a machine spindle or in an adaptor screwed to the machine spindle. See figures 66 and 68, pages 34 and 35.

SHARPENING ANGLE—The "dish" angle on the face of a Spur Shaper Cutter, measured in an axial plane, from the plane of the face. On a Helical Shaper Cutter it is the angle from the horizontal to which the fixture is tilted before being revolved into the correct helix angle setting for grinding the cutting face of a tooth. See figure 47, page 19, and figure 44, page 17.

SHARPENING STEP—The axial distance between the most advanced and least advanced portions of the cutter tooth on a Helical Shaper Cutter. The length of the sharpening step plus the chip clearance and overtravel allowance determine the minimum recess width for a Helical Shaper Cutter. See figure 47, page 19.

SHOULDER—A step limiting the diameter of the back on a Shaper Cutter. See figure 58, page 28.

SIDE RELIEF—Cutting relief behind the involute cutting edges of a Shaper Cutter Tooth. See figure 44, page 17.

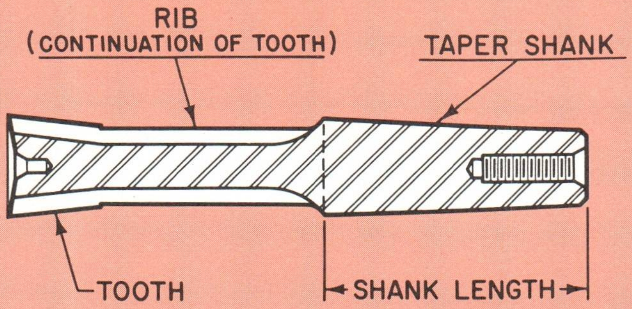


Figure 67—Shank Type Shaper Cutter with Stiffening Ribs.

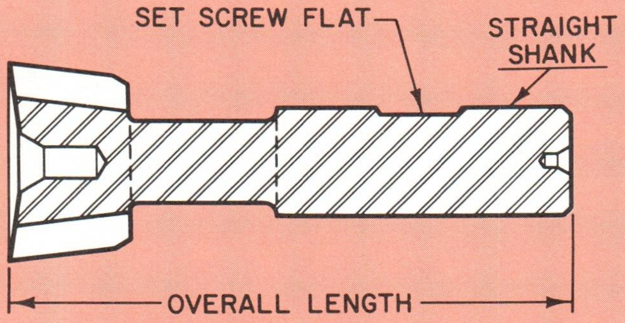
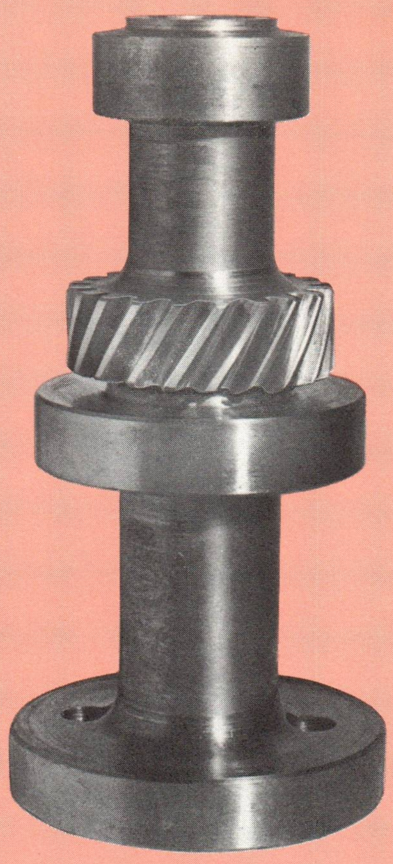


Figure 68—Shank Type Shaper Cutter with straight shank.



SIDE RELIEF ANGLE—The angle of Side Relief measured at the Pitch Line. See figure 25, page 11, and figure 44, page 17.

SIDE TRIMMING — A non-generating application of Involute Shaper Cutters where the cutter axis coincides with the part axis and the cutter has the same number of teeth as the part. The Cutter is rotated through a small arc in each direction to separately form the opposite tooth flanks on the part. See figure 64, page 32.

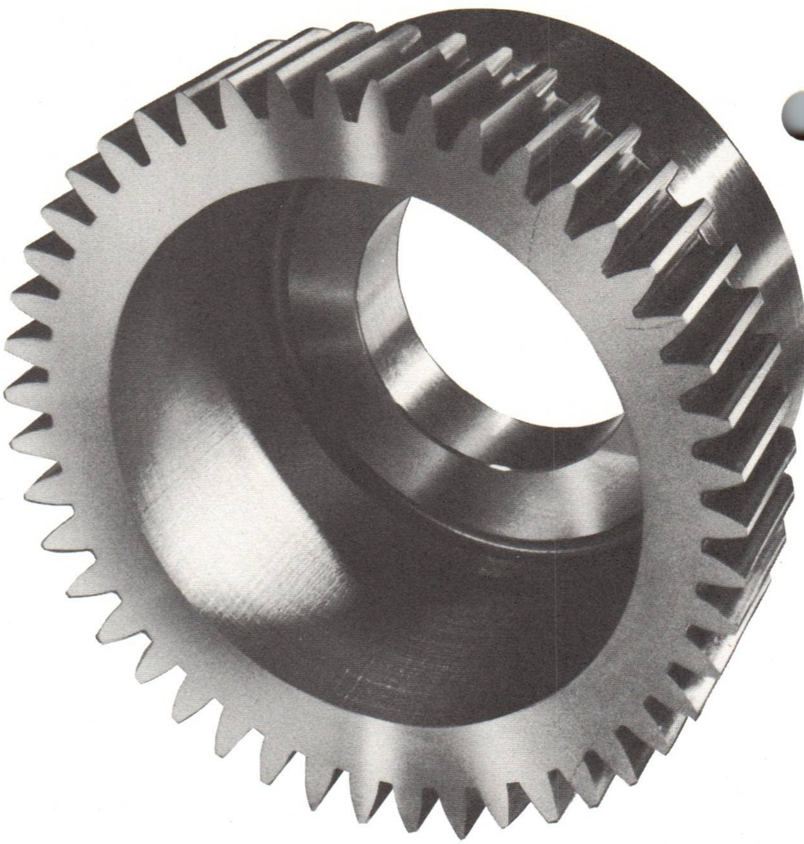
SPUR SHAPER CUTTER — A Shaper Cutter with involute profile teeth whose centerlines lie in axial planes. They are suitable for cutting spur gears or straight splines. See figure 13, page 9.

STIFFENING RIB — Axial extensions of the teeth on Shank Type Shaper Cutters, extending from the cutter head to the shank. They are reduced in tooth thickness to allow clearance for the grinding wheel sweep. By increasing the over-all diameter of the neck these ribs increase the stiffness of the cutter. See figure 67, page 35 and figure 20, page 9.

SYKES CUTTER—A term sometimes used to describe cutters for generating Herringbone and single or double helical gears. See preferred term: HERRINGBONE CUTTER.

TANGENT APPROACH — An approach consisting of a plane surface tangent to the involute surface of the cutter tooth. The intersection of these two surfaces approximates a straight line lying in a plane parallel to the cutter axis. See figure 35, page 15.

THICKNESS — The overall thickness of a Shaper Cutter measured from the highest point of the cutting face to the back of the cutter. See page 28, figure 58 and page 29, figure 59.



TIP FOULING—Undesirable cutting by the extreme tip (corner) of the Shaper Cutter tooth during the generating action in such fashion as to cut away the involute at the minor diameter of an internal gear. See figure 54, page 25.

TOTAL INDICATOR VARIATION (*tiv*) — The difference between the maximum and minimum indicator readings during a checking cycle.

TOOTH LENGTH—The length of the Shaper Cutter tooth, measured from cutting face to chamfer. See figure 28, page 13. On a spur cutter, the length is measured in the axial direction, and along the helix on a helical cutter.

TOPPING SHAPER CUTTER—A Shaper Cutter which, as it produces the tooth, also cuts the top of the gear tooth to produce a specified gear diameter.

TRIMMING — Removal of metal from the flanks of gear teeth near their tips by flanks of the cutter teeth so that true involute contact is lost at these points. The connotation usually conveys accidental or unintentional excess removal of metal, and an action not under close control, even though some tip relief on gear teeth is frequently desirable. See figure 32, page 14, and figure 53, page 25.

UNDERSIZE—The amount, at a specified point in its life, that the operating diameter of a Gear Shaper Cutter is smaller than the Nominal Pitch Diameter.

UPHILL SIDE—The trailing flank of a cutter tooth on a RH Helical Gear Shaper Cutter when viewed from the face and rotated counterclockwise. See figure 44, page 17.

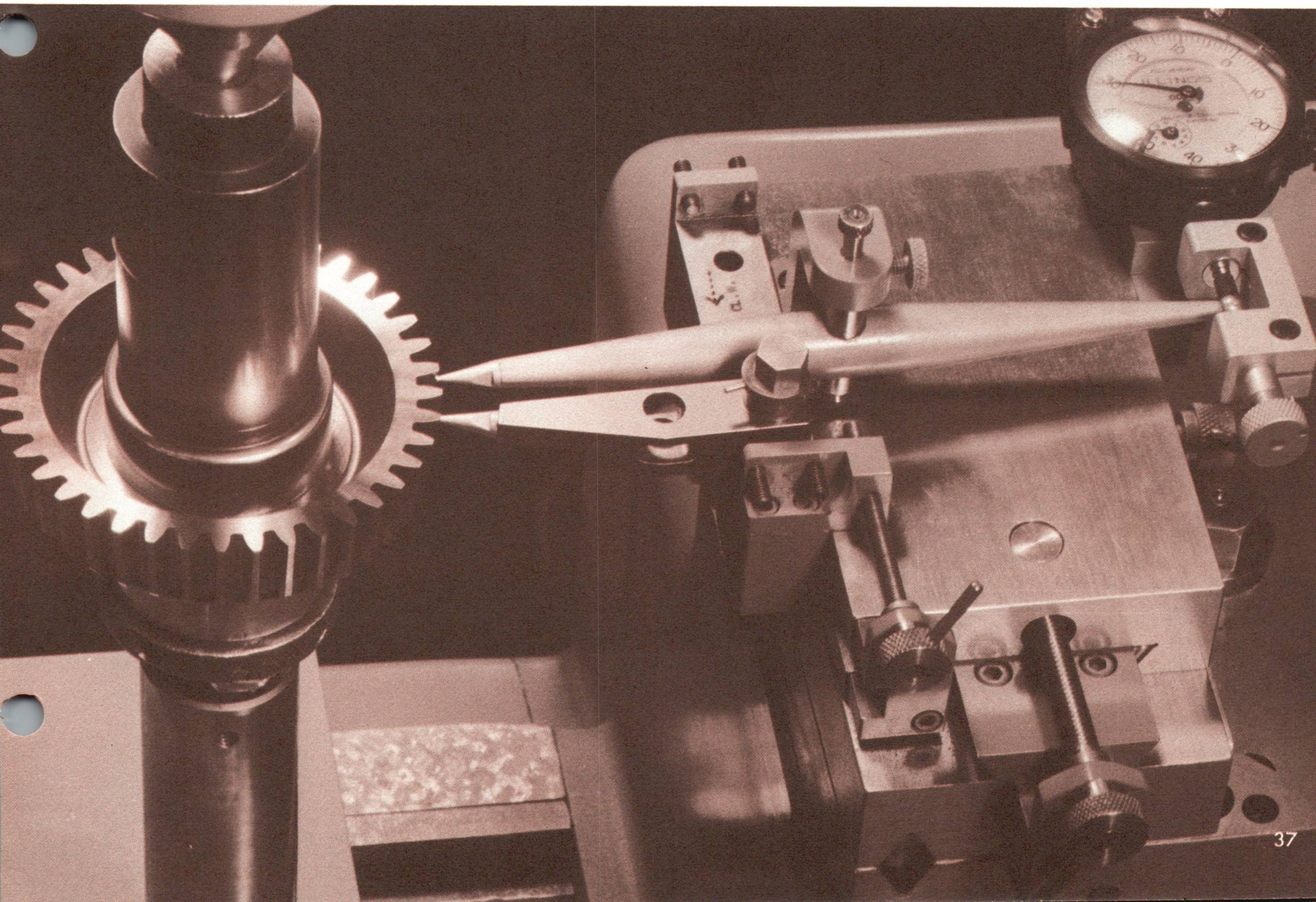
The leading flank of a cutter tooth on a LH Helical Gear Shaper Cutter when viewed from the face and rotated counterclockwise.

USABLE LIFE—The axial length of the Shaper Cutter tooth which is usable to cut gears to the given specifications. See figure 28, page 13.

WALL—The metal between the counterbore and the roots of the teeth on Shaper Cutters. See figure 59, page 29.

WEB—The axial distance from Inner Face to Back on a Shaper Cutter. See figure 58, page 28.

Checking the Tooth spacing of a Shaper Cutter using the model 3712 Illinois Tool Works Automatic Tooth Spacing Camparator.



Tolerances

Tolerances on the involute profile are based on checking behind the cutting edges in a transverse plane. Theoretically the projected image of the tooth cutting edges on a helical cutter is not exactly correct when the involute is generated in the transverse plane, but the error is negligible.

Tolerances in some cases vary with the pitch and the cutter diameter and in some cases vary with the style of Shaper Cutter. For example, greater tolerance values are specified for hub and deep counterbore styles than for shank or disc type. These greater tolerances do not necessarily reflect greater actual variations in the elements themselves since the fundamental quality is the same. All are ground on the same machines, with the same techniques. Larger tolerances in the case of some styles are to allow for the difficulty in securing equal repetitive readings after the cutters are removed from the grinding arbors and placed on other arbors for inspection.

Helical cutters due to greater complexity require slightly larger tolerances on some elements. However, the fundamental quality again (as above) is not necessarily measured by the tolerance values since some increase in tolerances is required by the complexity of cutter geometry and limitations in securing duplication of repeated readings.

Application of tolerances must be made with full understanding that commercial measuring equipment requires .0001 for instrument and observational errors.

PRECISION TOLERANCE vs. STANDARD TOLERANCE—The necessary accuracy in Shaper Cutters must be considered in the same light as requirements for hob accuracy. A class B hob properly mounted and operated on a machine in good condition will produce better gears than a class A which is improperly mounted or operated on a poor machine. Similarly the additional cost of a Precision Shaper Cutter is lost unless mounting, operating, and machine conditions enable the user to secure the benefits of the better cutter accuracy. Under best conditions product quality may be somewhat better with a Precision cutter, under average to poor conditions no difference will be noticeable.

Illinois Tool Works will be glad to make recommendations for a Precision Tolerance Shaper Cutter wherever a customer's requirements indicate its desirability.

In many cases a satisfactory compromise is secured by the use of a Standard Tolerance cutter with an indicating band since a reduction in Cutter Pitch Diameter runout, as mounted, may be secured by its use.

Published tolerances apply only to standard items, or special items with proportions similar to standard items. Specified tolerances cannot, in general, be applied to tools of extreme proportions or special design, although they provide a guide to reasonable tolerances for application to special Shaper Cutters.

In order to keep as up-to-date as possible on current industry tolerance standards, ITW elects to print these as a separate item. If you do not have current tolerances, we will forward a copy on request.

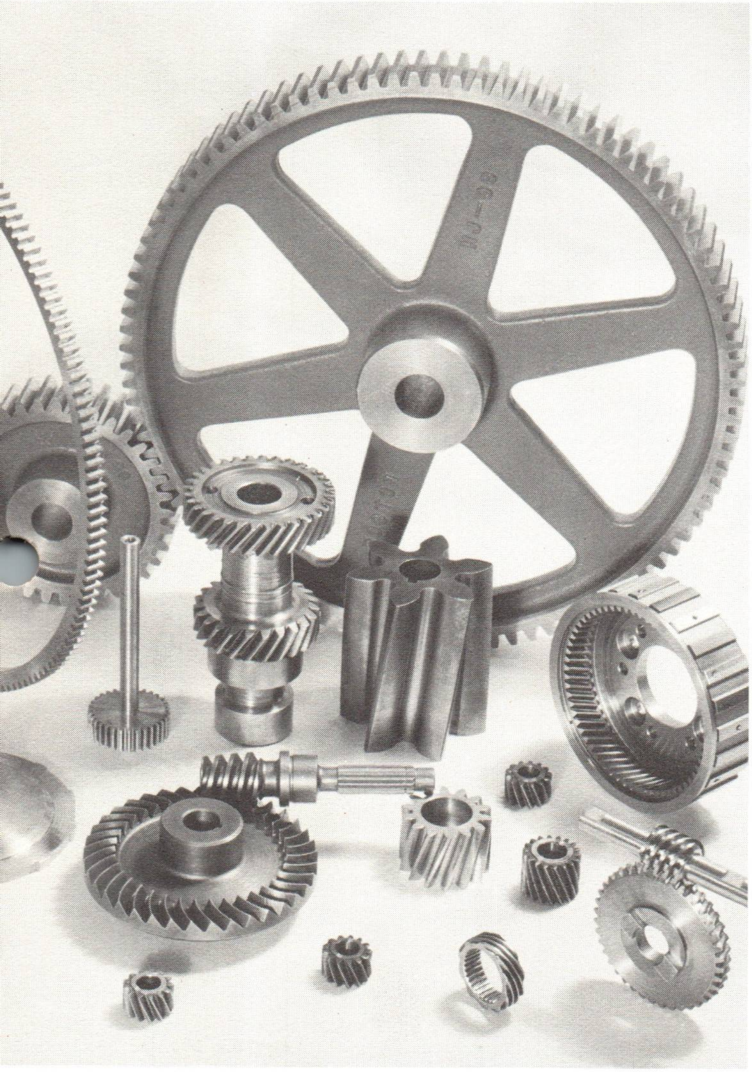


Photo illustrates a small portion of the wide variety of gears cut by ITW gear generating tools.

MARKING OF INVOLUTE SHAPER CUTTERS:

All ITW cutters have a minimum marking as follows:

SPUR CUTTERS

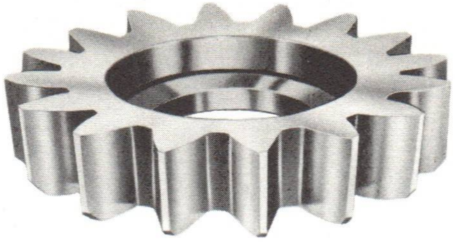
	Marked
Diametral Pitch	D P
Pressure Angle	P A
Base Diameter	B D
Number of Teeth	N
Whole Depth of Cut	W D

HELICAL CUTTERS

Normal Diametral Pitch	N D P
Normal Pressure Angle	N P A
Number of Teeth	N
Whole Depth of Cut	W D
Helix Angle	H A
Lead	Lead

HERRINGBONE CUTTERS

Transverse Diametral Pitch	T D P
Transverse Pressure Angle	T P A
Number of Teeth	N
Whole Depth of Cut	W D
Helix Angle	H A
Lead	Lead



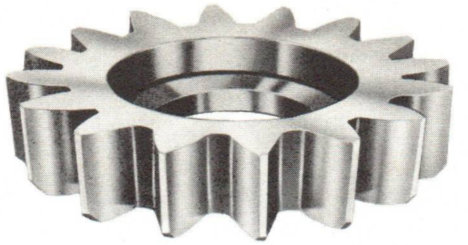
ILLINOIS STANDARD GEAR SHAPER CUTTERS

CARRIED IN STOCK

FULL DEPTH 20° p.a. GEAR SHAPER CUTTERS

2000 Series

Diametral Pitch	Pitch Diameter, Inches	Size of Hole, Inches	Number of Teeth	Whole Depth of Tooth, Inches	Order by Illinite® Number
3	4	1 ¼	12	.7500	**2050**
3	5	1 ¾	15	.7500	**2051**
4	4	1 ¼	16	.5625	**2001**
4	4	1 ¾	16	.5625	**2002**
4	5	1 ¾	20	.5625	**2052**
5	4	1 ¼	20	.4500	**2003**
5	4	1 ¾	20	.4500	**2004**
5	5	1 ¾	25	.4500	**2053**
6	3	1 ¼	18	.3750	**2005**
6	4	1 ¼	24	.3750	**2006**
6	5	1 ¾	30	.3750	**2054**
7	3	1 ¼	21	.3215	**2007**
7	4	1 ¼	28	.3215	**2008**
7	5	1 ¾	35	.3215	**2055**
8	3	1 ¼	24	.2813	**2009**
8	4	1 ¼	32	.2813	**2010**
8	5	1 ¾	40	.2813	**2056**
10	3	1 ¼	30	.2250	**2011**
10	4	1 ¼	40	.2250	**2012**
10	5	1 ¾	50	.2250	**2057**
12	3	1 ¼	36	.1875	**2013**
12	4	1 ¼	48	.1875	**2014**
12	5	1 ¾	60	.1875	**2058**
14	3	1 ¼	42	.1607	**2015**
14	4	1 ¼	56	.1607	**2016**
14	5	1 ¾	70	.1607	**2059**
16	3	1 ¼	48	.1406	**2017**
16	4	1 ¼	64	.1406	**2018**
16	5	1 ¾	80	.1406	**2060**
18	3	1 ¼	54	.1250	**2019**
18	4	1 ¼	72	.1250	**2020**
20	3	1 ¼	60	.1120	**2021**
20	4	1 ¼	80	.1120	**2022**
24	3	1 ¼	72	.0937	**2023**
24	4	1 ¼	96	.0937	**2024**
32	1 ½	½	48	.0708	**2061**
32	3	1 ¼	96	.0708	**2025**



ILLINOIS STANDARD GEAR SHAPER CUTTERS

CARRIED IN STOCK

STUB DEPTH 20° p.a. GEAR SHAPER CUTTERS

2000 Series

Diametral Pitch	Pitch Diameter, Inches	Size of Hole, Inches	Number of Teeth	Whole Depth of Tooth, Inches	Order by Illinite® Number
3-4	4	1¼	12	.5625	**2026**
3-4	4	1¾	12	.5625	**2027**
4-5	4	1¼	16	.4500	**2028**
4-5	4	1¾	16	.4500	**2029**
5-7	4	1¼	20	.3215	**2030**
5-7	4	1¾	20	.3215	**2031**
6-8	3	1¼	18	.2813	**2032**
6-8	4	1¼	24	.2813	**2033**
7-9	3	1¼	21	.2500	**2034**
7-9	4	1¼	28	.2500	**2035**
8-10	3	1¼	24	.2250	**2036**
8-10	4	1¼	32	.2250	**2037**
10-12	3	1¼	30	.1875	**2038**
12-14	3	1¼	36	.1607	**2039**

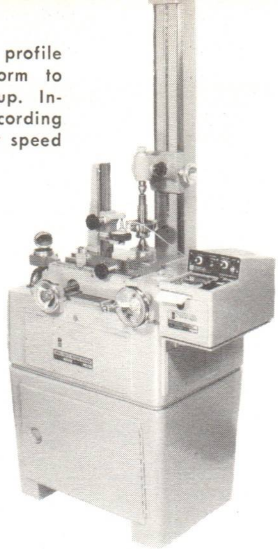
FULL DEPTH 14½° p.a. GEAR SHAPER CUTTERS

1000 Series

4	4	1¼	16	.5625	**1001**
4	5	1¾	20	.5625	**1023**
5	4	1¼	20	.4500	**1002**
6	3	1¼	18	.3750	**1003**
6	4	1¼	24	.3750	**1004**
6	5	1¾	30	.3750	**1024**
7	3	1¼	21	.3215	**1005**
7	4	1¼	28	.3215	**1006**
8	3	1¼	24	.2813	**1007**
8	4	1¼	32	.2813	**1008**
8	5	1¾	40	.2813	**1025**
10	3	1¼	30	.2250	**1009**
10	4	1¼	40	.2250	**1010**
10	5	1¾	50	.2250	**1026**
12	3	1¼	36	.1875	**1011**
12	4	1¼	48	.1875	**1012**
12	5	1¾	60	.1875	**1027**
14	3	1¼	42	.1607	**1013**
14	4	1¼	56	.1607	**1014**
16	3	1¼	48	.1406	**1015**
16	4	1¼	64	.1406	**1016**
16	5	1¾	80	.1406	**1028**
18	3	1¼	54	.1250	**1017**
18	4	1¼	72	.1250	**1018**
20	3	1¼	60	.1120	**1019**
20	4	1¼	80	.1120	**1020**
24	3	1¼	72	.0937	**1021**
24	4	1¼	96	.0937	**1022**

INVOLUTE PROFILE

Laboratory-type—variable involute profile instrument analyses gear tooth form to establish production machine set-up. Instrument incorporates electrical recording and large screen optical setting for speed and accuracy.

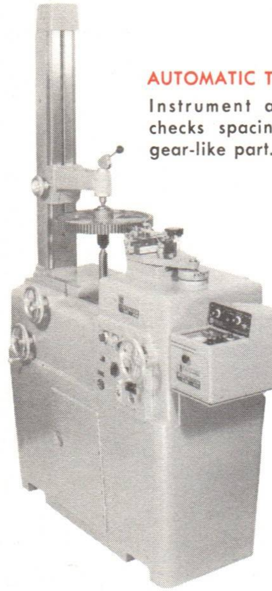


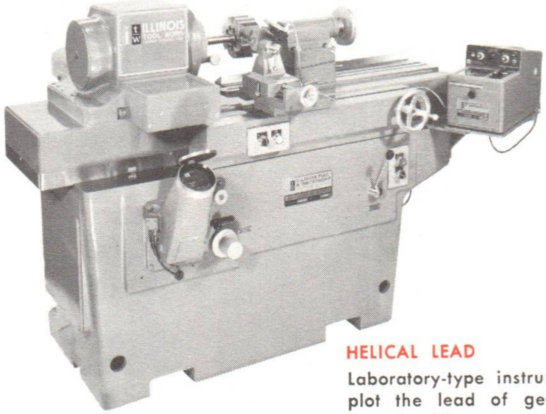
ITW® Gear Measuring Instruments

Helpful production man's friends reduce rejects — improve scheduling and delivery

AUTOMATIC TOOTH SPACE COMPARATOR

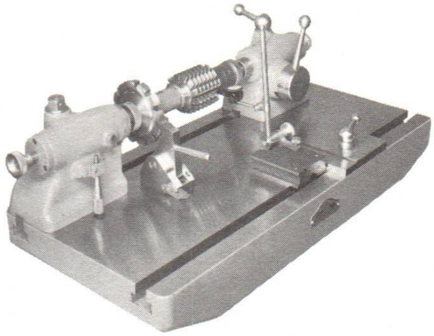
Instrument automatically indexes and checks spacing of all teeth on gear or gear-like part. Produces chart of the check.





HELICAL LEAD

Laboratory-type instrument is designed to plot the lead of gear teeth, worms or threads—big screen optically set for accuracy and speed.

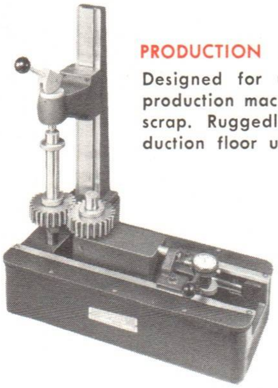


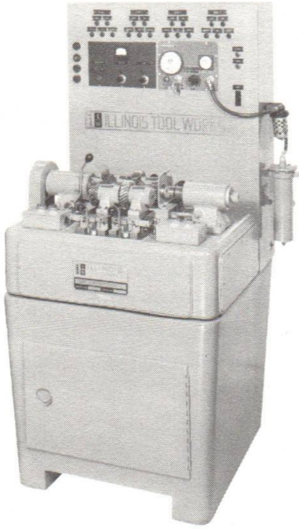
HOB AND CUTTER SHARPENING CHECKER

Accurately measures gash spacing, parallelism, rake, runout and checks for wobble of tools after sharpening.

PRODUCTION GEAR CHECKER

Designed for use next to the production machine. Saves time, scrap. Ruggedly built for production floor use.



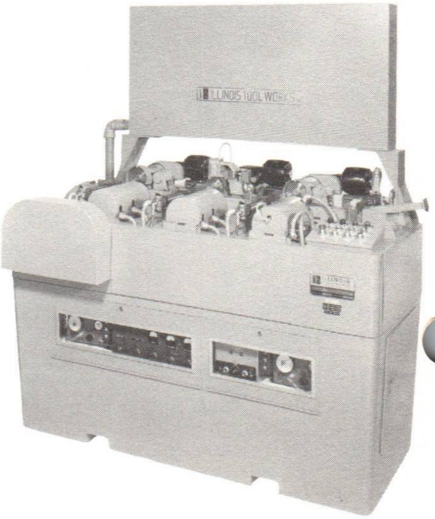


SEMI-AUTOMATIC CLUSTER GEAR CHECKER

Four master gear stations simultaneously checks all four gears of the cluster automatically. Unit requires manual loading.

AUTOMATIC FINAL GEAR INSPECTOR

Unit performs all inspection checks as well as complete automatic loading and sorting. Available in one, two and three station units.



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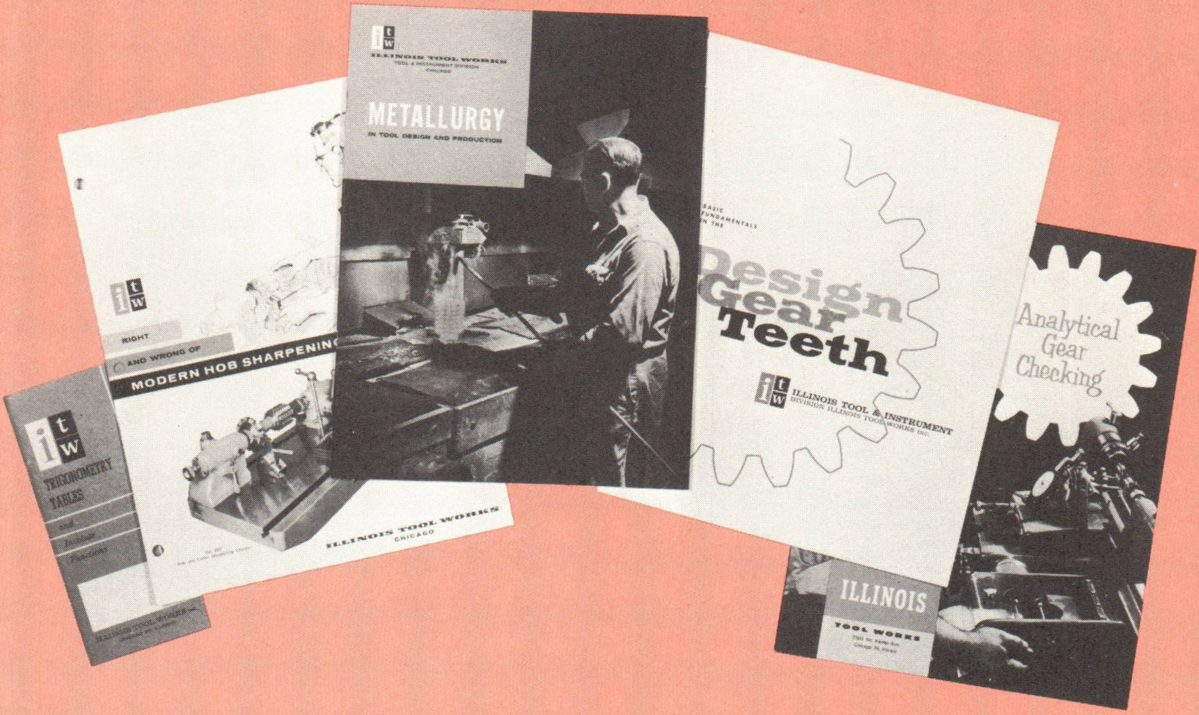

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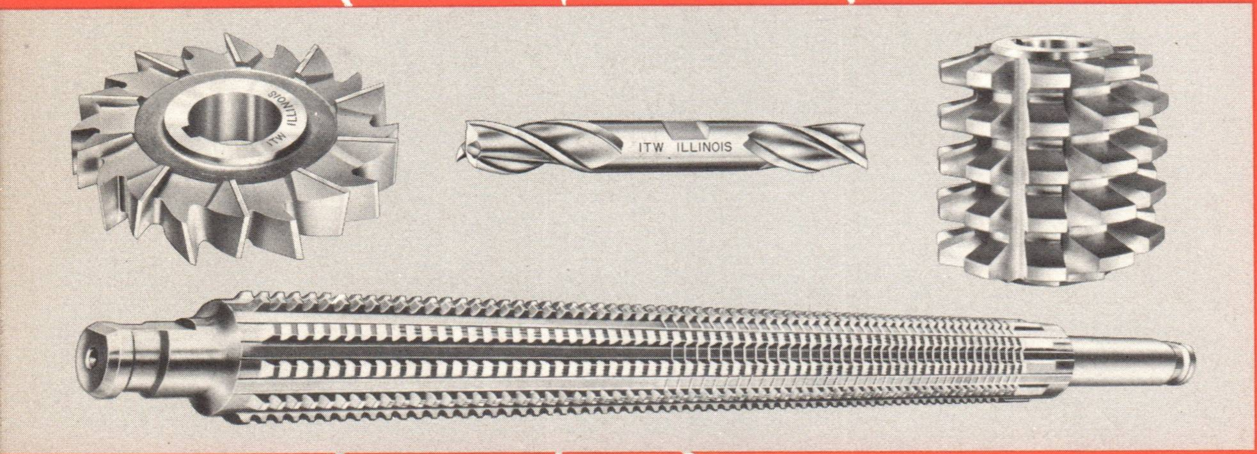

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